Development of an Integrated River Management Strategy

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8. An Integrated River Management Strategy (IRMS) for the Tillamook Bay Watershed

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LIST OF ABBREVIATIONS

AFS	American Fisheries Society
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
CAFO	Confined Animal Feeding Operation
CCMP	Comprehensive Conservation Management Plan
cfs	cubic feet per second
COE	United States Army Corps of Engineers
CWA	Clean Water Act
CZM	Coastal Zone Management
dbh	diameter-breast-height
DEM	Digital Elevation Model
DSL	Division of State Lands
DSR	Damage Survey Reports
EFH	Essential Fish Habitat
ELJ	Engineered Log Jam
EO	Executive Order
ESA	Endangered Species Act
ESEE	Economic Social Environmental and Energy
FEMA	Federal Emergency Management Agency
gcc	grams per cubic centimeter
GIS	Geographical Information System
GLO	General Land Office
GWEB	Governor's Watershed Enhancement Board
HMGP	Hazard Mitigation Grant Program
IRMS	Integrated River Management Strategy
LIDAR	Light Detection and Ranging
LWD	Large Woody Debris
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
NEP	National Estuary Program
NEPA	National Environmental Protection Association
NGVD	National Geodetic Vertical Datum of 1929
NFIP	National Flood Insurance Program
NMFS	National Marine and Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination Service
NRCS	National Resource Conservation Service
NWI	National Wetland Inventory
NWS	National Weather Service
ODFW	Oregon Department of Fish and Wildlife
OWEB	Oregon Watershed Enhancement Board
OCS	Oregon Climate Service
OCSRI	Oregon Coastal Salmon Restoration Initiative
ODF	Oregon Department of Forestry
ODOT	Oregon Department Of Transportation
OSGC	Oregon State Game Commission
OWRD	Oregon Water Resources Department
pcf	pounds per cubic foot
psf	pounds per square foot
PWA	Phillip Williams and Associates
QA/QC	Quality Assurance/Quality Control
SCS	Soil Conservation Service
STATSGO	State Soil Geographic Data Base
SPRR	Southern Pacific Rail Road
TBNEP	Tillamook Bay National Estuary Program
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Service

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1. Introduction

This project puts forward an integrated river management strategy that combines flood risk reduction with salmon recovery. The strategy was developed by an interdisciplinary team using the Tillamook Bay Basin as a pilot study area. The resulting approach is intended to be transferable to other watersheds facing similar natural hazard risk and natural resource concerns. Analyses of the fluvial, biological, and institutional elements comprising the Tillamook Bay river system were conducted at a number of spatial scales. The results were used to identify opportunities and constraints and develop a planning level Integrated River Management Strategy (IRMS) for Tillamook. Documentation of the Tillamook IRMS is provided in this report targeted to the lay audience, with a special emphasis on meeting the needs of watershed councils with regard to their growing responsibilities under provisions of the Oregon Plan.

1.1 Background

In recent years, and especially during and after the Pacific Northwest floods of 1996, field staff for the U.S. Fish & Wildlife Service (USFWS) noticed an increasing trend in flood recovery work involving the replacement and new construction of riverbank protection and other flood control works in Oregon's waterways. The cumulative impacts of these interventions conflicts with our increasing efforts and investments to recover and protect the river ecosystem essential for sustaining endangered salmon species.

There is a need to step back and reconcile the growing conflicts between these two activities that are occurring in Oregon's rivers. A proactive strategy needs to be developed for managing our rivers, encouraging actions and activities that can provide mutual benefits for flood risk reduction and salmon recovery.

Fortunately the requirements for this kind of strategy are largely complimentary. Restoring river systems and functions to accommodate flooding and improve the effectiveness of existing flood control works are both key components of a successful river management strategy.

To restore and manage rivers for fish requires protecting the riverine habitat that is sustained by the natural processes of the river system and allowing for some degree of disturbance and sediment movement during floods. This is best accomplished by managing the river system and watershed as a whole. The task of the river manager in the 21st century will therefore be to integrate the requirements of flood management with the enhancement of environmental resources—as well as accomodating other human uses of the river such as water supply and recreation—into a integrated river management strategy.

The U.S. Fish & Wildlife Service (USFWS) contracted with Philip Williams & Associates, Ltd. (PWA) to assist the USFWS, the U.S. Environmental Protection Agency (USEPA) and the U.S. Army Corps of Engineers (USACE) as a co-sponsors, in conducting this project.

The USFWS, USEPA and USACE are supporting this project to develop and promote a new approach for addressing flood-related issues in Oregon. The IRMS involves a flexible approach by which public officials, watershed groups and others can identify strategies and actions for addressing flood-related issues in ways that also assist the recovery of native fish and wildlife.

1.2 Project Goal and Objectives

1.2.1 Project Goal

This project is unique in that, to date, there has not been a comprehensive approach to floodplain management focusing on both flood risk reduction and salmon recovery. Therefore, the goal of this project is to initiate a fundamental change in the way society has traditionally responded to flooding, so that flood hazards are managed and reduced, but not at the expense of fish and wildlife habitats.

1.2.2 Project Objectives

The goal of this project can best be achieved by pursuing objectives that promote a balance between the use of river systems and floodplain lands by humans, fish and wildlife. These objectives guide the project to results that reduce risk to these populations and would demonstrate how a change in the way things are currently done can actually increase benefits to all and lead to a sustainable use of the land. Accordingly, the objectives of the project are to:

1. promote a balance between human safety, property protection, and fish and wildlife habitat needs;
2. establish the multiple benefits of floodplain management and salmon recovery;
3. demonstrate floodplain restoration as a viable flood management tool;
4. provide a science-based model for restoration;
5. provide a methodology for adaptation and implementation by watershed councils;
6. identify demonstrated watershed management strategies that reduce losses from future floods in the Tillamook Basin;
7. identify benefits to floodplain resources (especially salmon) occurring from flood management strategies

1.3 Project Approach and Report Overview

In Section 3, the resources and functions of a river system are described and provide the proper context for subsequent development of the IRMS. Elimination of conflicts between river processes and human use of the floodplain is the framework for developing the management strategy and for determining where actions should best be applied.

An interdisciplinary approach was used to analyze flood and habitat-related issues using a number of techniques at a number of spatial scales. The analyses are integrated to identify flood risk reduction and salmon recovery opportunities and constraints in the Tillamook Bay Basin. This approach provides a framework for developing a specific strategy to address flood and habitat-related issues in the Tillamook Bay basin, one that is sensitive to critically important spatial and temporal issues. The steps of the approach and the resulting Tillamook Bay IRMS, are inherently flexible, so that changes can be made based on the results of monitoring as the river system responds to new management influences.

The project approach had six basic steps which correspond to the major report sections.

Step One: Characterize the Functions of River Systems Specific to Flood Risk and Salmon Recovery
This step reviews the processes by which flooding creates aquatic habitat and how human flood response may disrupt this relationship. This step is covered in Section 3.

Step Two: Characterize Flood Risk and Salmon Distribution in Oregon
This step characterizes Oregon floodplains with respect to flood risk and salmon distribution. Simple geographic information system analyses are performed using available data at the State scale in order to identify floodplains with conditions similar to Tillamook and to help inform our understanding of the Tillamook Bay's position within the region. This step is covered in Section 4.

Step Three: Review the Environmental History Of the Basin
This step describes the evolution of the Tillamook Bay Basin River System using narrative and spatial analyses at the basin and ecoregion scale. The review focuses on the historic pattern of flood and fire and how human management of the forests, rivers, floodplains, and estuaries has degraded aquatic and terrestrial habitat and increased the cost of flooding. This step is covered in Section 5.

Step Four: Characterize the Components of the Tillamook Bay River System
In this step a suite of assessments, including the use of analytic tools, such as GIS, are used at a variety of spatial scales to describe the fluvial, biological, and institutional components of the Tillamook Bay River System and how they interact with the uplands, lowlands, and estuary, the primary expressions of the landscape. Each of the components is described with a number of distinct analyses that include: climate,

landform, hydrology, hydraulics, river morphology, vegetation, salmon, land use, transportation, and damage trends. The assessments most significant in developing the IRMS are covered in Section 6. A more extensive set of assessments is covered in Appendix A.

Step Five: Identify Opportunities and Constraints
Findings from Step Four are used together with spatial analyses to identify conflicts and opportunities within the Basin. These are the foundation of the integrated river management strategy. This step is covered in Section 7.

Step Six: Develop the Integrated River Management Strategy
This step uses the spatial analysis done in Steps Four and Five to identify actions appropriate for the Basin and the most effective locations for the application of those actions. This step is covered in Section 8.

1.4 Applications of the Approach

Application of this approach to the Tillamook system is intended to serve as the basis for the conceptual level development of the IRMS. The approach can then be transferred to other river systems of varying scale and in other geographic regions, to establish other strategies tailored to the particular river system where it is used.

The initial application of this approach to the Tillamook Bay system required that the project team, USFWS and other partners make informed judgements to prioritize the functional importance of various portions of the landscape. These judgements and resulting priorities have been clearly stated, but may differ somewhat from those that might be made during subsequent applications of the approach by a local watershed council or some other group.

The important point here is that the approach is intended to provide a common starting point from which community-based actions can be taken to develop alternative strategies for addressing flood management; i.e., the strategy developed by the project team is one of several strategies that may eventually be developed for a given river system. However, it is likely that the same general types of strategies and actions for resolving flood and habitat-related issues will be developed for a given system, possibly with somewhat different areas of spatial emphasis.

This anticipated consistency of outcomes is one reason that the application of the approach holds promise as an effective way to address flooding and habitat problems caused by human actions. Another reason is that this type of spatial approach could be used to develop regional, basin, or watershed-specific strategies that could each have its own set of strategies and actions. Many of the strategies may look similar to one another, regardless of spatial scale, although they would vary to some degree depending on specific landscape conditions, patterns of development, or community values.

1.5 USFWS Coordination

The USFWS was a partner with the project team, providing GIS and biological expertise. The project team relied on the USFWS for coordination of the project with the Oregon Plan for Salmon and Watersheds and other ongoing state and federal salmon recovery activities that the USFWS is involved in, as well as other flood reduction strategies being developed by the Corps of Engineers and local governments.

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CHAPTER 2: Conclusions and Recommendations

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2. Conclusions and Recommendations

2.1 Introduction

Many conclusions have been drawn from this investigation and the preparation of this report. The conclusions presented below represent a selection of the more significant observations concerning the opportunities for mutually beneficial management of floodplains, for protection and recovery of salmon resources and flood risk reduction. Conclusions and associated recommendations are intended to support the development of an Integrated River Management Strategy (IRMS).

Since a strong emphasis of this investigation was placed on the use of spatial analysis, the conclusions and recommendations are grouped in a progressive sequence of spatial scales paralleling those presented in the remainder of this report. The most detailed conclusions and recommendations are made at the spatial extent of the Tillamook Basin lowland floodplain. Planning level recommended actions are mapped at this extent to illustrate a potential combination of strategies and actions that could comprise an IRMS for the Tillamook lowlands (Figure 2-1). The main areas mapped in this figure are the Active Floodplain Zone, the Floodplain Zone, and the Tidal Zone. Distinctions were made between these zones because of the unique set of physical processes and geomorphic responses that occur in each area. The mapped Tidal Zone is a subset of the estuary where opportunities to restore tidal processes and estuary ecosystems are present. The mapped Floodplain Zone and Active Floodplain Zone are subsets of the lowland portion of the Tillamook Basin where opportunities to preserve and restore Fluvial and flood processes are present. More general conclusions and recommendations are made at the spatial extent of the Tillamook Bay Basin and the State of Oregon.

Conclusions derived from work within the Tillamook Basin are grouped according to the broad spatial division of the river system, including the estuary, lowlands and uplands. These landscape divisions are intended to identify areas within the Basin with similar natural processes and geomorphologies. These commonalities allow for the identification of a number of strategies and actions that are appropriate in a general areas with out having to identify a specific project site or problem set.

Conclusions from non-spatial aspects of this investigation, including observations on public policy and flood response permitting, are then described followed by a summary of general conclusions concerning future work on Integrated River Management Strategies (IRMS) in Tillamook and elsewhere. Since issues associated with flood response permitting were the primary catalyst for the USFWS to initiate this project, conclusions and recommendations for this subject have been kept separate from more general public policy findings.

2.2 Tillamook Bay Basin Scale

2.2.1 The Estuary

Tidal saltmarshes are some the most productive ecosystems in terms of biomass. Drainage basins with proportionally larger estuaries may be inherently more productive for salmon than basins with smaller estuaries, at least for those species with extended periods of estuarine residency. At the turn of the century, the Tillamook Bay estuary system had the highest productivity for salmon on the Oregon Coast. The most abundant species was chum salmon, which spawn in the lowland river systems and rear in tidal habitats.

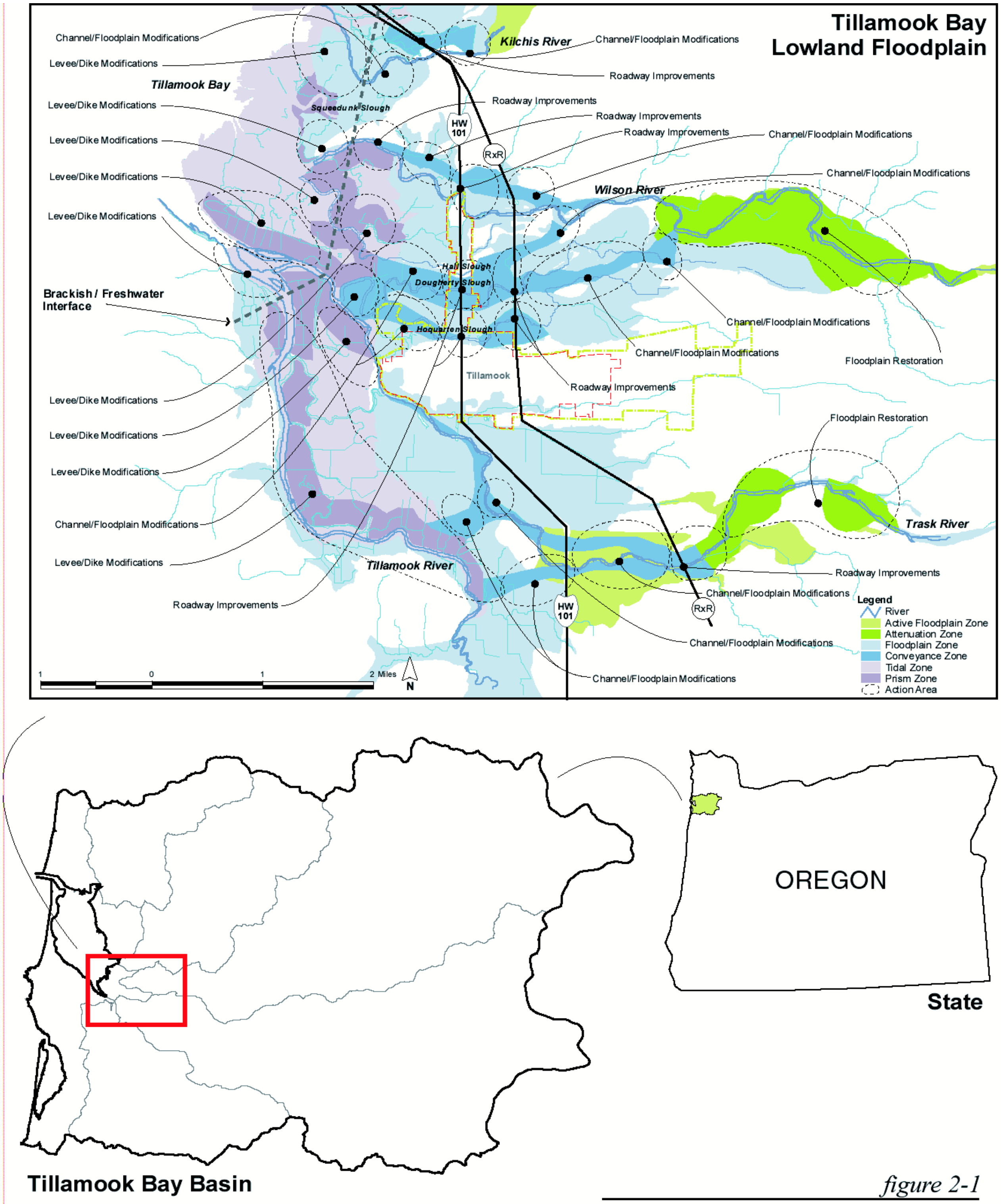

figure 2-1

Tillamook Bay Lowland Floodplain
Integrated River Management Strategy and Concept Plan

PWA

Recommendation: Prioritize tidal marshes and tidaly influenced floodplains for flood management efforts, because of the potential for relatively quick gains in salmon production with the restoration of natural processes from the daily ebb and flood of tides, compared to non-tidal parts of the system.

Along the Oregon coast, the effects of a rising sea level are most pronounced in the Tillamook area. The Oregon coast is experiencing a range of positive and negative sea level trends due to sea level rise, as tempered by tectonic movement. Coastal uplift is relatively less in the Tillamook Bay area of the Oregon coast and this area is therefore being inundated by a rising sea level faster than other coastal areas, by about 2-millimeters per year. In a 100-year time span this would amount to 200 millimeters, or about an 8 inch rise in sea level. For a typical intertidal mudflat slope in Tillamook Bay, assumed at one foot vertical to 250 feet horizontal, this implies marsh vegetation could retreat inland up to 170 feet.
Recommendation: In developing IRMS strategies in coastal areas, include serious consideration of relative sea level rise and its effect on invalidating design assumptions and the life expectancy of public works and ecosystem restoration projects. Plan and design ecosystem projects to work with long term processes, such as sea level rise, as well as shorter term processes, such as flooding and tidal action.

There is a lack of long-term tidal elevation data and hydraulic data for the lowland tidal river reaches. There is no direct monitoring of streamflows in the lowland valley reaches of the river systems, where the bulk of flood damages occur and where floodplain management needs are most pressing, because the lowland rivers can be tidally-influenced. Tidal monitoring in the bay has been sporadic and of short duration. This lack of basic hydrologic data inhibits the effective development of flood management efforts. The recent installation of additional streamflow and tidal gauges by the TBNEP will benefit future monitoring and adaptive management actions for flood management efforts.
Recommendation: Prioritize development of the basic hydrologic data necessary for making informed decisions on management of lowland floodplain lands and resources. Pursue funding for long-term operation of tide and streamflow gauges.

2.2.2 The Lowlands

An extensive amount of lowland floodplain vegetation has been converted to agricultural lands, but relatively large contiguous wetlands exist in tidal portions of the lowlands. Large areas of intact wetland plant communities exist in the tidal portions of the lowlands. The brackish-to-freshwater reaches of the marshes, sloughs and rivers present habitat opportunities for osmotic transition, highly productive foraging environment and deep channels for predator avoidance. Tidal forest is still found in very limited areas of the Tillamook lowlands. The largest remaining area is the forest surrounding Hoquarton Slough within the Urban Growth Boundary of the City of Tillamook.
Recommendation: Protect these existing lowland natural areas, and consider restoration efforts for contiguous land parcels to expand the natural functions of these resources for habitat and flood management.

About two-thirds of all low-gradient stream channels in the Tillamook Bay basin, with high aquatic habitat potential, are found in lowland areas. This is important because such channels tend to be those most responsive to inputs of wood and sediment, and are generally recognized as being capable of providing the most complex and productive aquatic habitats when in properly functioning condition.
Recommendation: Implement flood response actions to manage wood and sediment in lowland river reaches with consideration for habitat impacts.

The extent of lowland forests and the abundance of large wood in the Tillamook lowlands had been significantly affected by agricultural land conversion and stream cleaning activities prior to 1939. An analysis of historic air photos confirm the perceptions of older basin residents that most dramatic changes to lowland riparian forests occurred a very long time ago. Riparian forests along each of the lower rivers and sloughs examined had been highly fragmented by 1939, the date of the first comprehensive aerial photography effort. Most areas they once occupied have been dominated by sparsely forested, highly discontinuous, or treeless conditions since that time. The presence and abundance of large wood in the tidal reaches of the Tillamook Bay rivers and sloughs declined steadily from 1939 to 1994. Flooding should continue to deliver large wood and other organic materials to the lowlands.
Recommendation: Make provisions to accommodate the deposition and movement of large wood in the lowland rivers to restore ecosystem complexity.

The intensity of human land use increases dramatically in the lowlands. Interventions are more prevalent and significant in this part the river system and the potential for flood and fish impacts is greater. Constraints to the development of an IRMS are more prevalent and inflexible because of the longevity of the human presence and established infrastructure.
Recommendation: Apply a bold and creative vision to allow the restoration of floodplain features and natural processes to demonstrate the natural resiliency of a river system to restore aquatic habitats and provide natural flood reduction capabilities.

The historic construction of levees and dikes often violated engineering design recommendations at the time. Tillamook lowland river and slough channels were channelized and simplified as the population grew and floodplain lands were converted to agriculture. Levee and dikes were built alongside the channels to protect investments in farming and maximize the land area farmed. Flood control structures built on the immediate bank of a river channel and on opposite banks of the channels violated the design guidelines provided in the early 1900s.
Recommendation: Consider the restoration benefits of setting back levees to reduce flood elevations and protecting setback levees with vegetation to reduce erosion, especially since both techniques were advocated 100 years ago.

The high intensity of water use in the lowlands is likely a factor influencing water quality (including temperatures) in many lowland streams. Most of the documented water quality problems in the Tillamook Bay basin are spatially associated with lowland areas. Sources of water quality problems include confined animal feeding operations and municipal and other sites with pollution discharge (NPDES) permits. Water diversions are also most abundant in or near the lowlands.
Recommendation: Give equal consideration to habitat impacts from reduced water quality and the more evident physical expressions of habitat, such as riparian and stream channel conditions, in addressing lowland water use issues.

2.2.3 The Uplands

Successful management of the lowlands begins with proper management of the uplands. Upland areas represent the largest portion of the Tillamook Basin and serve as source areas for many of the river system physical and biological processes. The large expanse of the upland landscape collects precipitation and conveys water, sediment and organic materials through the river system to the lowlands.
Recommendation: Implement fundamental strategies for managing the uplands to improve the success of a lowland IRMS. These strategies would include: 1) Managing the runoff of water where it first falls as precipitation; 2) Managing the availability, recruitment

and movement of large wood in upland river reaches; and, 3) Managing impacts at stream crossings.

Opportunities for large-scale salmon recovery may be most practical where species diversity and availability of productive habitat exists on public lands. Large scale salmon recovery efforts on private lands may face difficulty because of the variety of land ownership, land uses and land management techniques. However, ecosystem restoration is most effective if actions are implemented at a watershed scale, without the constraints of imposed property boundaries.
Recommendation: Prioritize opportunities for large-scale salmon recovery efforts in the uplands where salmon habitat exists on public lands.

2.2.4 The Basin

The Tillamook Bay Basin has some of the most pronounced interactions of salmon and flood issues in Oregon and is a priority river system for integrated management of fishery resources and flood risk reduction. Five salmon species are distributed within the Tillamook Bay Basin and their abundance has dramatically declined since the turn of the century. Tillamook County has experienced repetitive flood damages and had the highest damages of any Oregon county during the 1996 floods.
Recommendation: Review and refine the IRMS developed in this investigation, and incorporate into the Corps Feasibility Study efforts in Tillamook to assist in efforts to identify solutions for achieving common objectives for flood risk reduction and salmon recovery.

Seasonal flooding, which helped to shape the lush Tillamook lowland landscapes that have attracted human populations over the centuries, has also sustained salmon populations over the millennia. The physical features of the basin provide opportunities for human use of natural resources throughout the river system and sustain the economy and lifestyle of the residents and tourists to the area. Human use of the land initially evolved with recognition of constraints imposed by the natural environment, such as flooding. Flooding now represents one of the predominant natural constraints to human land use in the river system. Conversely, it represents the one of best natural opportunities for recovery of salmon.
Recommendation: Make a concerted public education effort to place the natural role of flooding in a proper context, so that provisions of an IRMS may be better understood, debated and decided by the local governments, land owners and the public at large.

2.3
State and Ecoregion Scale

FEMA regulatory floodplains are the primary tool for land use management in floodplains, yet these data may become rapidly outdated as river systems adjust over time and impart error and uncertainty in the land use planning process. FEMA regulatory floodplains are based on a statistical 1 in a 100 annual chance of a flood occurring within a designated boundary. Many assumptions are used to establish regulatory floodplains and subsequent floods often invalidate the land use information provided on floodplain maps. Geomorphic floodplains, or floodplains based on mapped soil units having an annual one to five percent chance of flooding, generally coincide with mapped FEMA regulatory 100-year floodplains, but are based on observed soil conditions and reflect land areas where flooding is known to have occurred.
Recommendation: Consider soils data and geomorphic analysis to augment traditional FEMA floodplain mapping procedures to identify flood hazard areas.

The distribution of salmon species in Oregon is pervasive throughout regulated floodplains in the state. The floodplain as defined by the National Flood Insurance Program (NFIP) encompasses the area with a 1% annual chance of flooding. It was established as a

tool to delineate risk for purposes of administering programs to reduce public and private losses due to flood hazards. FEMA is currently proposing that the purpose of the flood hazard reduction ordinance be expanded to also maintain streams in their natural state to the maximum extent possible as a way to assure that the natural floodplain functions related to protecting riparian habitat for fish are protected; and to assure no net loss of ecological functions of floodplains.
Recommendation: Consider conservation and restoration of salmon habitats in managing Oregon floodplains and enforcing floodplain regulations. In many instances, these activities would lend support to the objectives of the NFIP and contribute to the reduction of flood risk to human life and property. The new FEMA model ordinance is currently under review by the USFWS and NMFS (Carey, 2001). Even if it is approved, its adoption will remain voluntary for members of the National Flood Insurance Program; however, adoption and compliance of the ordinance is anticipated to reduce the risk of non-compliance with provisions of the ESA and streamline consultations with federal agencies, should they be required for floodplain development projects.

The coastal ecoregion presents a high potential for impacts between salmon habitats and human land use. Salmon distributions are highly concentrated along the coast and habitats are highly diverse and complex in the larger estuarine systems. Significant amounts of precipitation occur on the coastal uplands and runoff processes are susceptible to change from human land use practices. Population growth and tourism is increasing in coastal areas and development is increasing in floodplain areas to accommodate this trend.
Recommendation: Give coastal river systems priority consideration for integrated river management strategies for flood risk reduction and salmon recovery.

Estuaries provide vital habitat for salmonids, but public policy and regulatory recognition of this role of estuaries is lacking. Studies in several Oregon and Washington estuaries (particularly the Salmon River and South Slough of Coos Bay) have provided strong evidence of the importance of estuarine habitat to salmonids (Simenstad and Bottom, 2001). Results of recent studies increasingly support this conclusion. Tidal habitats provide a very favorable environment for salmonid rearing, and increased estuarine residence time often translates into increased smolt survival. However, protocols for evaluating in-stream and watershed conditions (for example, the ODFW's Aquatic Habitat Inventory methodology, and OWEB's 1999 Watershed Assessment Manual) and agency recognition of important salmon habitat (for example, ODFW's designated Core Areas and DSL's Essential Salmon Habitat maps) have almost completely omitted consideration of tidal channels. This omission creates potential problems throughout the range of anadromous salmonids, but particularly in basins such as Tillamook Bay, where the estuary is large in proportion to its drainage basin. In the Tillamook Bay basin, the estuary is central to flood management decisions and also central to salmonid production, yet policy recognition of the estuary's role in salmonid production is lacking, so community decisions on flood management are not fully informed by knowledge of the importance of estuarine resources to salmon.
Recommendation: Prioritize the inventory and assessment of tidal habitats with the same consideration given to freshwater habitats, so that flood management and other land-use decisions may not conflict with salmonid conservation goals.

2.4 Public Policy

Public planning and policy structure is non-spatial and/or is often incompatible with spatial correlation. The Oregon Plan for salmon and watersheds provides statewide benchmarks for natural resource management.

The Tillamook Bay Comprehensive Conservation Management Plan (CCMP) lays out 62 actions intended to address the most significant environmental problems in the Tillamook watershed. A review of these plans reveals little relationship to existing spatially defined policies intended to regulate land use actions. ***Recommendation:*** Develop and make available spatial information in a format that can be used to refine the implementation framework of these and other initiatives to achieve flood hazard reductions and habitat restoration.

There is a lack of a multi-objective policy framework. Flood hazard reduction efforts administered by the COE and FEMA are often solely based on hydraulic criteria and can be in conflict with habitat restoration/ESA related issues that are based on biological and geomorphic criteria. The term "multi-objective management" has not been addressed by the regulatory framework. Regulations and programs of individual agencies have been established to meet specific mandates, which are typically single objective task oriented. The complex mission of an IRMS is to balance ESA objectives with flood hazard reduction objectives. Local governments are mandated to develop a program to achieve Goal 5 for all significant resources sites through the adoption of comprehensive plan provisions and land use regulations. The Goal 5 resources include water bodies, fish habitat, wildlife habitat, riparian corridors, and wetlands. ***Recommendation:*** Consider Goal 5 provisions as a vehicle to implement the multi-objective IRMS approach.

There is a lack of an integrated comprehensive planning viewpoint. Both flood hazard reduction planning and salmon restoration efforts have emphasized restrictions on property uses within the floodplain. Not only is there a currently notable lack of incentive to develop in a manner that conserves and restores habitat, but government actions often tend to encourage additional encroachments in the floodplain. ***Recommendation:*** Use land use policies to creatively strengthen existing established commercial centers outside of flood prone areas and increase their drawing power, instead of increasing sprawl onto floodplains, as a way to alleviate the ever-increasing development pressures on the floodplain.

2.5 Flood Response and Waterway Permitting

Flood response actions are often uncoordinated and inefficient. Typically, public policy authority for investigation is at the federal level, while authority for review is at the state level, and authority for implementation is at the local level. These authorities often remain segregated to their respective levels and mechanisms for interaction or support are lacking. This has, in part, led to uncoordinated and inefficient flood response actions.
Recommendation: Improve interagency flood response coordination.

Some discontinuity appears to remain between the regulatory intent of waterway permits and recent regulations. The original intent of regulatory permits, often established decades ago, does not necessarily address current resource management concerns; e.g., requirements of the Section 404 removal/fill permit program and objectives of the Endangered Species Act. ***Recommendation:*** Undertake a comprehensive review to ensure that required permit actions support current regulations and change with changing regulations. For example, current Section 404 permit requirements should be reviewed to evaluate their consistency with the newer ESA 4(d) evaluation considerations for Limit 12: Municipal, Residential Commercial and Industrial (MRCI) Development and Redevelopment. The 404 application process tends to remain focused on the project site, with required documentation of offsite conditions limited to contact information for adjoining property owners, whereas the 4(d) rules promote a more comprehensive evaluation of potential impacts from a waterway project with respect to the geomorphic functions of the particular reach of the river system.

A lack of consistency, accuracy, compatibility and connectivity in existing databases impedes efforts to analyze cumulative biological impacts of permit actions. Spatial locations in the permit databases, which would be helpful to locate permit actions using a GIS, are inconsistent; for example, some are stated in lat/long coordinates (COE), others in township/range (NRCS). Some database entries are spatially inaccurate, showing permit locations on the equator or in the Pacific Ocean! Several disparate and disconnected agency permit databases exist because of the variations in jurisdiction among agencies that regulate waterway impacts, agencies that evaluate water quality, and agencies responsible for fish and wildlife resources. For instance, the FEMA database lists flood response actions not in waters of the United States and thus not permitted and recorded by COE or DSL. There are also issues of software and hardware incompatibility among these databases. USFWS uses Paradox, while DSL has used Wang, for example. These systems are inaccessible to each other without first converting to a common format. Meanwhile, the COE RAMS database is not transferrable to file at all, and can only be used on-screen or in print-outs.
Recommendation: Establish standardized interagency procedures to facilitate the recording, entry and transfer of permit data to and from databases and GIS. Encourage proper coordination between field staff, database staff, and GIS staff, to ensure that adequate QA/QC procedures are used to guide database development. Make efforts to consolidate and update databases to enable consistency and efficiency in the permit process.

Flood response permitting lacks a cumulative or interactive impact analysis. Fragmentation and complexity of the permitting process is an enormous and well documented problem. There are numerous examples of policy "disconnect." The underlying intent of these permits does not correspond to the primary concerns of an IRMS (habitat restoration; water quality; and quantity; fish passage; flood hazard reduction) and, consequently, cumulative impacts on the function of the river system can be significant.
Recommendation: Consider two existing vehicles to facilitate integrated planning and assessment: 1) the NEPA framework, together with; 2) the OWEB Watershed Assessment Manual. The cumulative impact analysis component of NEPA can be used to correlate actions with the three main ESA concerns (flow rates; water quality; habitat) and to define impacts on thresholds as specified by Oregon Plan benchmarks. The OWEB Manual provides tools for evaluating watershed functions and condition, and helps local and regional groups prioritize types and general locations for habitat restoration actions.

There is often a discrepancy between the resulting permit action and the recorded description. Permit data generally presents information on proposed actions; the completed actions are not well documented. For instance, an applicant is likely to use a different amount of riprap than what was requested in the permit application and permitted. There are likely many waterway flood response actions that are not documented in regulatory permits because they are not reported.
Recommendation: Expand the regulatory permit program to require documentation of the resulting "as-built" condition, possibly through the use of economic incentives borne by the permit applicant. Wetland removal/fill premit programs do require post-implementation monitoring of mitigation activities, but enforcement of those requirements is sometimes poor due to high staff workloads and low funding levels. Improved follow up in such cases is recommended, as is increased funding needed to implement followup.

Floods should be viewed as opportunities for monitoring to obtain valuable scientific data to refine river management strategies. Post flood activities primarily involve efforts to restore public safety and protect public infrastructure, as they should. ***Recommendation:*** Flood response plans should include planned efforts to document flood characteristics and post-flood conditions of habitat and channel/floodplain morphology. These efforts may include the identification of high water marks from designated locations using standard procedures, repetitive survey of river channel sections to assess scour and deposition trends, and aerial and ground level photography and videotaping of the dynamic processes at work during a flood event. These data could be used for adaptive management purposes and to refine assumptions made in the continuing development of hydrodynamic models.

2.6 Conclusions Concerning Integrated River Management Strategies

There is a lack of basic scientific and technical data necessary for the effective management of floods and fishery resources. Our investigations in the Tillamook Basin began with expectations for an abundance of data for the river system because of the earlier efforts by the Tillamook National Estuary Project (TBNEP). While significant data were developed for the uplands at a compatible coarse spatial scale, we found a severe lack of data at a finer scale for the lowlands and estuary. ***Recommendation:*** Target data acquisition at the lowland and estuarine portions of the Tillamook Basin. Recent efforts by the Corps to obtain lowland topographic data as part of the Feasibility Study could be augmented by state-of-the-art airborne Light Detection and Ranging (LIDAR) surveys. Repetitive LIDAR surveys over time would be a cost-effective way to document changes in the lowlands to guide adaptive management actions for the IRMS.

The framework for an effective integrated river management strategy is already in place, developed from lessons learned by others. Much independent research has been done in the disciplines of flood management, salmon recovery and landscape ecology. It has been only recently that interdisciplinary investigations have begun in earnest and these have often been prompted by severe flood events. ***Recommendation:*** Make efforts in Tillamook, and other Pacific Northwest communities, to communicate and meet with other entities from the United States and overseas, who have dealt with similar experiences and developed aspects of river management strategies that could be adopted locally.

The hydrodynamic model currently being developed for the Tillamook Bay lowland river system will be a valuable decision making tool. The model is currently intended to be used to assess the effects of river management activities on hydrodynamic conditions including flood elevations, velocities, sedimentation, and channel scour. ***Recommendation:*** Extend model use to investigate salinity intrusion, temperature and other water quality parameters under different management strategies. Integrate this model with a 2-dimensional model of Tillamook Bay, in order to develop a better understanding of the link between the hydrodynamics of the bay and lowland river systems.

Multi-objective river management can imply multiple potential funding sources. As an example, the plans for a Napa River Flood Control project for the City of Napa in California was rejected three times by the local community because it benefited only those living in the floodplain. It also called for dredging and massive bank stabilization that would have dramatically impacted the ecology of the river system. Consequently, the project grew from an effort focused only on flood control for a few miles of channel, to a watershed-wide initiative, resulting in many benefits and funding sources for continued work.

Recommendation: Tillamook has an opportunity to be a similar nationally-recognized community capable of attracting the diverse range of funds achieved by the Napa Community.

A cornerstone of the proposed IRMS is the establishment of a clear set of performance criteria, and periodic monitoring standards to ensure that the IRMS is on a trajectory to achieve these criteria. The development of an IRMS is immensely complex and includes ecological, economic, social, hydrological, and cultural issues. The interaction and linkages of many of these issues are difficult to predict and unforeseen circumstances--positive and negative--may arise as an IRMS is implemented and becomes established over time. Secondly, the conditions in the watershed are not static in time and are subject to the geomorphic evolution of the river system, episodic events such as fire and flood, and external factors such as conditions in the ocean, changes in legislation or funding opportunities.

Recommendation: Make a commitment among participants in an IRMS to ensure availability of funding and resources for long-term monitoring to track the performance of an IRMS.

An IRMS should allow the accommodation of natural processes to reduce the long term operations and maintenance costs typically associated with traditional flood control endeavors. One of the guiding principles in the IRMS is to reduce costly frequent maintenance activities that would also disrupt key habitat.

Recommendation: Perform innovative and sound economic investigations during the development and evaluation of IRMS actions to equitably assess the economic benefit and cost of restoring natural processes relative to those associated with traditional flood control infrastructure.

Successful IRMS implementation will occur only with active, informed landowner involvement, and with public support and understanding of restoration goals and processes. Landowner involvement is essential from the very beginning of the site selection and site planning process.

Recommendation: Development of an IRMS should be a completely open process, perhaps updated through the TBNEP website.

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CHAPTER 3: River Systems

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3. River Systems

The purpose of this section of the report is to describe generally what a river system is, how it functions and how it is used. The role of flooding in a river system is explained, from both the standpoint of its dynamic nature as the lifeblood of the system, and as the predominant force that shapes and rearranges fish and wildlife habitats and provides natural resources for human uses. Our alterations of river systems to exploit these resources are briefly described, together with the consequences of our actions once we begin to prevent floodplains from flooding. Finally, the ways in which we have managed our uses of floodplains in river systems are discussed, with respect to past trends in flood control costs and flood damages, and future trends toward more sustainable floodplain management.

3.1 The River System

A river system is the expression of water on the landscape. Water, to a large extent, originates from precipitation in mountainous **uplands**, flows through floodplain-dominated **lowlands** and, in many cases, discharges to ocean **estuaries**. The water moving through each of these areas connects the landscape into one system, making it impossible to talk about the lowland and estuary without acknowledging the contribution to these areas made by the uplands. The floodplains of the lowlands are the areas where the conflicts between human flood risk and salmon habitat are most evident.

Over the past decades, we have used a number of engineering approaches to "control" flooding. These include regulating the amount of water in the river, and modifying the structure of both the channel and the floodplain. Other alterations have been made to increase the productivity of floodplain lands. These engineering approaches are very costly and, though effective for smaller floods, have not significantly reduced flood damages in large flood events. This, combined with an increasing desire to preserve ecological integrity, has begun to change the way we manage floodplains. Land managers are increasingly combining flood damage reduction goals with goals for preservation and restoration of aquatic and terrestrial habitats, and are attempting to use flooding as a way to create and maintain those habitats.

3.2 Flooding and Floodplain Functions

River systems transport water, sediment, and nutrients from the land to the sea, shaping and reshaping floodplains, deltas, and beaches, and regulating the salinity and fertility of the water and land. Floods facilitate these functions, by providing energy to introduce and transport materials in the river system, and in doing so, maintain biodiversity. In upland forests, heavy rains may cause landslides which can introduce wood and sediment to the river system. These materials are transported downstream to the lowlands, where they are deposited in channels and on floodplains, and reworked with the next flood. Flooding along lowland rivers may also introduce sediment and wood to the river system from riverbank and bed erosion. Flooding in the lowlands introduces a lateral dimension to the downstream movement of these materials, as floodwaters spill over riverbanks and then recede back into the channel as the flood passes. Flooding within the larger land areas of estuaries, where floodwater velocity and energy tends to diminish, typically results in the deposition of transported materials. However, tidal action in estuaries introduces another dimension to the movement of water as daily flood and ebb tides rhythmically flow, or aggressively surge inland with ocean storms and clash with river floodwaters flowing seaward. The dynamic mixing of water in the estuary during regular tides and infrequent storm surges results in complex patterns and reworking of sediment and wood, and a changing interface of fresh and salt water. This complexity is an essential part of the hydrological and ecological function of a river system.

Flooding, therefore, is a part of the dynamic nature of a healthy river system. The flood pulse is both a product of and an influence on geomorphic and hydrologic conditions. Flood pulses (Junk *et al.,* 1989) are one of the principle driving forces responsible for the existence, productivity, and interactions of the life forms in a river system (Figure 3-1). High instream flows and periodic overbank floods are needed to cleanse channels of accumulated sediments, build stream banks, cycle nutrients, transport gravel for spawning fish, and create landforms suitable for riparian forest recruitment.

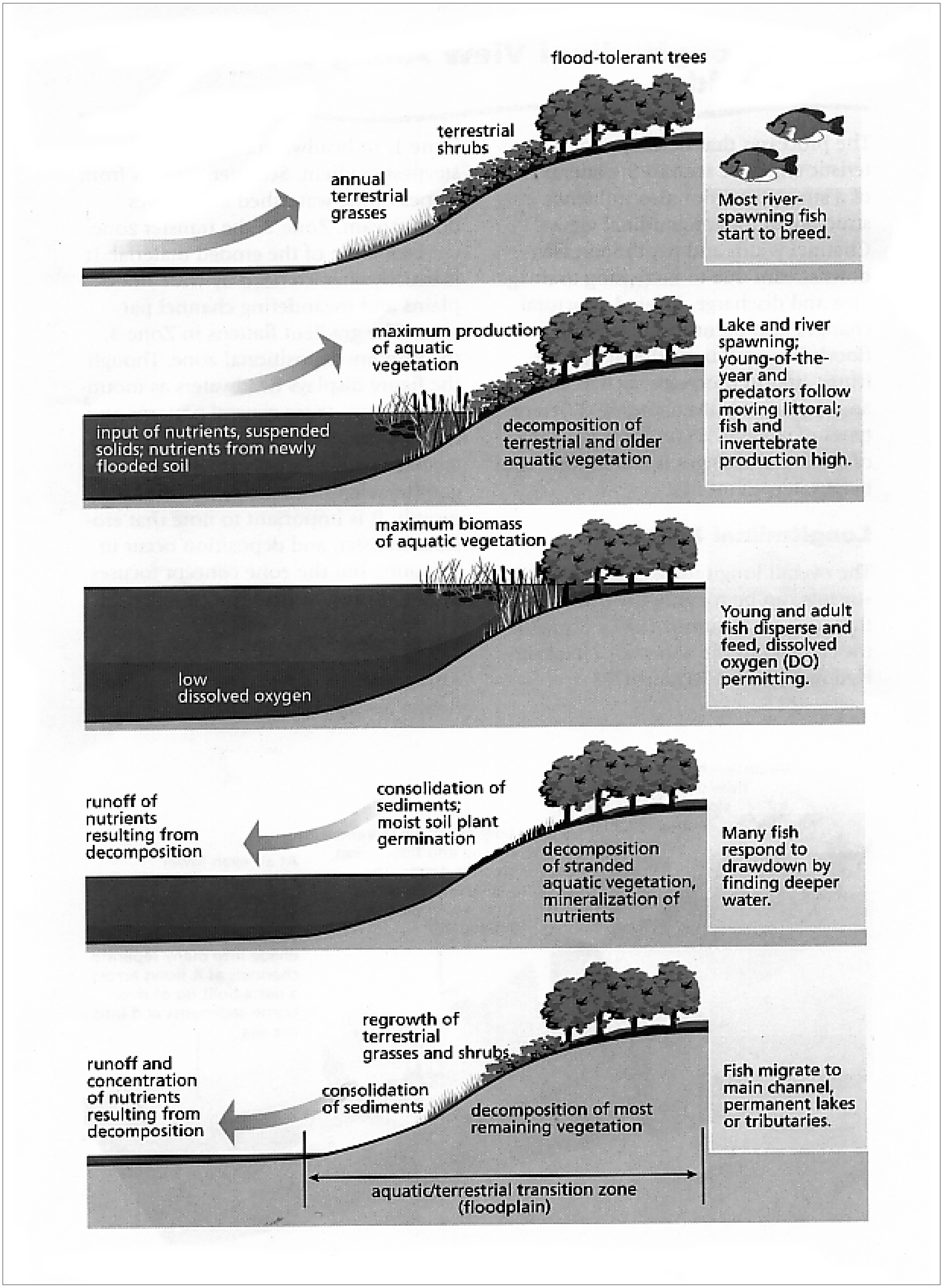

Figure 3-1. Schematic of the Flood-Pulse Concept Source: Bayley, 1995
A vertically exaggerated section of a floodplain in five snapshots of an annual hydrological cycle. The left column describes the movement of nutrients. The right column describes typical life history traits of fish.

Small frequent floods and larger infrequent floods are responsible for the creation and evolution of the lowland floodplains, with the size of floods in the lowlands directly related to the contribution of water from the uplands. More frequent floods are generally thought to maintain the form of a river in the short-term, while less frequent, higher magnitude floods affect river form over a longer time-scale. The constant readjustment of river form with these changing flows is called dynamic equilibrium. Seasonal flooding promotes the exchange of materials by facilitating erosion and deposition. As a result, flooding enhances seed dispersal, seedling survival, and the growth of many native plant species that occupy channel banks and floodplains (Hill *et al.,* 1991). In this way, flood pulses lead to a mosaic of habitats that determine the level of biological productivity and diversity in the river and on the floodplain (Petts, 1996).

Flooded lands in a river system, or floodplains, serve as both sources and sinks for transported material. They also dampen flood flows and provide diverse habitats. A floodplain is defined as the relatively level valley floor formed of sediment deposits (Anderson *et al.*, 1996) (Figure 3-2). In an unmodified state, this is the flat area adjacent to a river channel which is periodically flooded when flows exceed the channel capacity (Bren, 1993). From the flood pulse concept, the floodplain is the aquatic/terrestrial zone where the production of aquatic vegetation, decomposition of vegetation and consolidation of sediments occurs (Figure 3-1).

During flood events, a river overflows onto its floodplain, and the capacity of the system to convey and store large volumes of water is temporarily increased. The storage of water on floodplains reduces the peak stage of flood events downstream as floodwaters spread out and are held on the floodplain. During this process, sediment, wood and nutrients are provided to surrounding riparian land and aquatic habitat, increasing floodplain productivity.

The ability of a river to overflow onto its floodplain helps to moderate bank erosion and channel change. Streamflow in rivers that are confined in canyons or between levees has greater power because the flow is concentrated into a small flow area and is deeper than if it were allowed to spread out. This concentrated stream power can result in bank erosion and channel changes that would be less severe if the river were able to overflow. In rivers with floodplains, water flow and volume spread out onto the floodplain during high flow events, reducing the stream power acting on the channel bed and banks. Lower stream power can result in more stable channels. Floodplains therefore serve as a kind of "pressure release valve" by moderating the rise of water levels and channel velocities during flood events.

Floodplain overflows can therefore lessen the destructive force of floodwaters. This benefits riparian habitats, by lowering the erosive force of flowing water to levels that can be withstood by the native vegetation important to fish and wildlife habitat. Human investments along the river system may also benefit because lower erosion potential can reduce damage to protected riverbanks. By allowing floodplains to flood, there may be less need for riverbank protection.

The ability of a river to overflow onto its floodplain helps to moderate the tendency of an otherwise constrained river channel to fill with debris and sediments. The murky brown color of floodwaters is an indication of the significant amount of sediment transported in a river system during flood events. The flow of sediment-laden floodwaters, carrying floating debris out of the river channel and across a wide floodplain, can result in wider distribution of sediment and debris as floodwaters recede. Shallow floodplain flows encounter more resistance from vegetation along

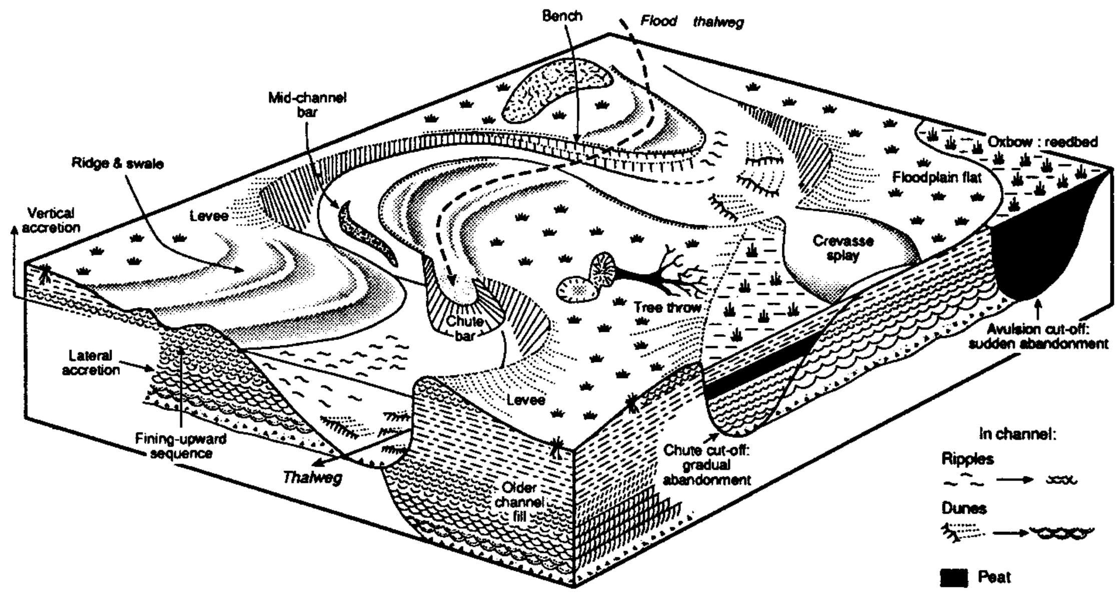

Figure 3-2 River Floodplain Landform Schematic Source: Brown, 1996

river banks and across the floodplain, causing the moving water to lose energy and deposit suspended sediment and debris. Where floodwaters first encounter the filtering effect of riverbank and floodplain vegetation, large amounts of sediment are deposited, forming low natural levees along the river channel. Natural floodplains are able to capture and store enormous volumes of suspended sediment spread over large areas, which helps reduce the amount of sediment transported to channels and estuaries downstream.

3.3 Flooding and Fish and Wildlife Habitats

Flooding alters the structural complexity of upland forest and lowland floodplain landscapes, and rejuvenates the plant communities that grow in them.

Over time, periodic flooding results in plant communities made up of a mosaic of vegetation species and ages. This complexity, in turn, supports a diversity of terrestrial and aquatic animal species, including salmon. Flooding contributes to species diversity by:

1. creating varied landforms that support diverse native plant communities;
2. creating a variety of habitats, including spawning habitat for fish;
3. creating low-velocity refugia for fish and other aquatic organisms during floods;
4. contributing to the aquatic food web by collecting, cycling, and transporting organic matter from the uplands to the lowlands and from the floodplain back to the channel;
5. maintaining water quality by filtering excess sediment and nutrients from flood flows and providing shade.

The riparian portions of floodplains have a great amount of structural complexity, and are highly functional parts of a river system. They often include complex arrangements of live trees and shrubs, downed wood and trapped flood debris. The functions of riparian floodplains lead to in-stream effects that shape and reshape salmon habitat (Figure 3-3). Flooding serves as the lifeblood to sustain these riparian functions and maintain habitats.

Flood flows mobilize and rearrange gravel and cobble deposits in the lowlands and estuary, left from previous flood events. They transport and redistribute sand and fine sediments from eroding banks or low bars on outside bends and from point bars. These newly formed channel features are colonized by a variety of native plant species, and provide accessible edge habitats. Flood flows also sort gravel deposits in a river channel as floodwaters recede. This results in river reaches with collections of gravel suitable for salmonid spawning habitat. When a flood retreats from the floodplain, the decreasing flows and water depths result in the deposition of sediments and debris on the floodplain. This enhances the build-up of natural mounds and ridges that can trap subsequent floodwaters and create shallow marshy basins on floodplains. These wetlands and other remnant channel features, such as oxbows, and scrolls (Figure 3-3), provide sheltered refuges for fish from high flows. This refuge habitat is especially important for juvenile fish, which need lower velocity and cleaner water to survive.

Floods also supply large wood and organic detritus to the river and its floodplain. Large wood affects the geomorphology and hydraulics of the stream, which, in turn, regulates light penetration to the stream, and the input of dissolved and particulate matter. Together, these functions regulate the food supply and energy expenditure of salmon.

Saturation of floodplain soils from flooding, and resulting elevated groundwater levels, enhance and sustain riparian vegetation and wetlands along rivers. Permeable floodplain lands can absorb large quantities of floodwater when made available for flooding, and vegetation and depressions in the terrain slow and hold the water and allow it to sink into absorbent soils. When flooding can recharge groundwater and raise water tables under floodplains in the winter and spring seasons, this stored water may slowly seep back to the river later in the year after floodwaters recede. Water released back to the river system in this way can benefit water quality by contributing cool groundwater during warm summer months. Floodplain groundwater can also contribute to the quantity of flowing water from upstream sources and reduce the chances of river beds and banks drying up and stressing vegetation and fish. In a sense, floodplains can be viewed as natural reservoirs that can provide storage of floodwaters both above ground, during flood events, and below ground after floods have passed.

Flooding provides sediment and nutrients to both the flooded lands and aquatic habitats (Federal Interagency Floodplain Management Task Force, 1996). As floodwaters pass over floodplain land, they capture soil particles and organic material rich in carbon and nutrients. These materials are transported across the floodplain at high flows to backwater basins, estuaries, secondary channels, and ultimately back to the river. These organic components provide microhabitats, food, and nutrients to sustain zooplankton, aquatic invertebrates, and small fish. By detaining floodwaters longer than in the main channels, floodplains also increase the residence time of these organics. This promotes greater energy use, higher food web productivity and improved water quality.

Floodplain vegetation also plays a role in water quality. Riparian trees and shrubs help to shade streambeds and maintain lower water temperatures. This is important

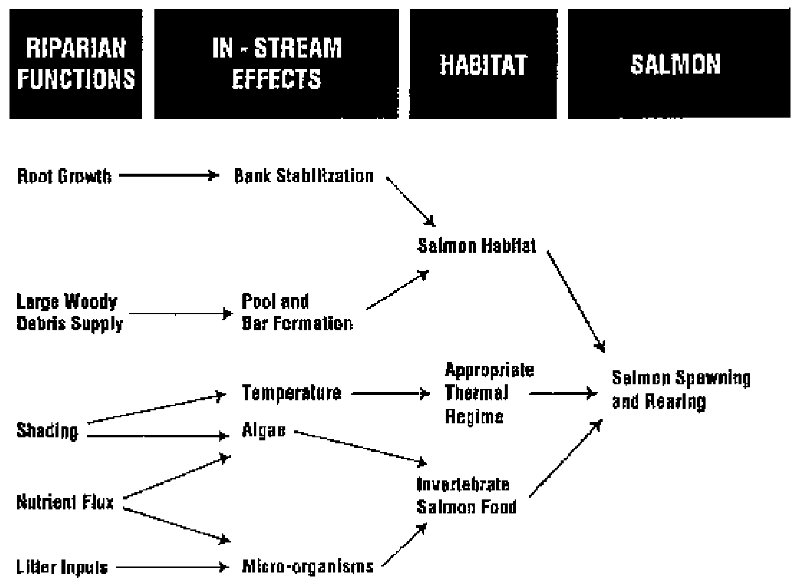

Figure 3-3. Riparian Functional Relationship to Salmon Source: Botkin *et al.*, 1995

because cooler water is capable of carrying more dissolved oxygen, which is is critical for salmonid health. Floodplain vegetation also helps in filtering sediment.

All these floodplain functions work together to shape and reshape the habitats within which salmon and other species have evolved, and to which they have adapted. Fish and wildlife have, over time, developed intricate physical, chemical and biological relationships linking them within the river system. These relationships--seen and unseen--can be damaged or destroyed when humans alter the river system.

3.4 Human Alterations of the River System

The increasing intensity of human use of upland forests, lowland floodplains, and estuaries has altered river system functions, and, in many instances, has increased the size and frequency of floods. Our occupation of floodplain lands has decreased our tolerance for periodic flooding.

Human land use has also altered the source, transport and deposition of water-borne materials through the uplands, lowlands, and estuaries of river systems. Timber harvesting on forested uplands has decreased forest cover while increasing the incidence of landslides and debris flows. This has resulted in an increase in the delivery of sediment to rivers, but without the accompanying natural delivery of large wood. Both these changes in river system inputs have had negative effects on terrestrial and aquatic habitat in the lowland and estuary areas downstream. Reduction of forest cover in the uplands and compaction of soils from logging and burns have decreased the natural ability of the forest to absorb water, thereby increasing both the speed and volume of water delivered to the river system as runoff. This in turn increases flood risk in lowland and estuary areas. The downstream results of these upland alterations have been further compounded by the fact that the increased flood risk in the lowlands is being met with increased development and occupation of the floodplain.

Floodplains are typically the most intensely used land areas in a river system. The earliest lines of transport and communication have typically been located along rivers, and this has led to the early development of floodplains. Floodplains are attractive for many uses because they offer large, flat tracts of land and abundant water. Riparian forests can be removed to create productive pasture and agricultural lands. Deposits of sand and gravel on floodplains and in river channels can be mined for use as aggregate in concrete. A variety of other commercial and industrial land uses is often found on floodplains for various reasons. As the number and value of these land uses has expanded to increase the productivity of floodplain lands, actions have been taken to protect the growing number of investments from flood risk. Many river flood control strategies have included actions that prevent floodplains from flooding.

The traditional assumption that flooding can be completely controlled has led to an over-reliance on man-made flood protection, and the development of flood control systems which constrain rivers into artificially narrow channels and isolate historic floodplains, eliminating or hindering their natural function. Floods have been viewed through the years as anything but a part of the natural life cycle of river systems (Friends of the River, 1996).

As flood control works are built and age over time, continued alterations in the river system often create new flood characteristics that may invalidate the assumptions used to design and build the old flood control facilities. For example, continued development and urbanization in our watersheds has resulted in pavement and efficient storm sewers that speed runoff. Because of the increased rate and volume of runoff, a statistical 100-year flow value from 20 years ago may be much less than that same statistical value today, and correspondingly, today's true 100-year floodplain may be larger than we believe (Figure 3-4).

Over the past two centuries, flood control practices have resulted in radical changes to floodplains. Dams, levees and dikes have been built to control flooding and protect floodplain developments. These responses, ironically, have created a false sense of security and have, in many cases, actually increased flood damages, because when flood control measures fail, flooding often occurs faster and with more disastrous consequences. In addition, human alterations have separated rivers from their floodplains. This has simplified the complex form of the channel and floodplain and reduced the functions provided by the interaction between water and land. This has had negative consequences for native vegetation, terrestrial animal species, and aquatic species like salmon. The following are examples of traditional engineering "solutions" to control flooding and the impact these practices have had on river morphology and salmon habitat.

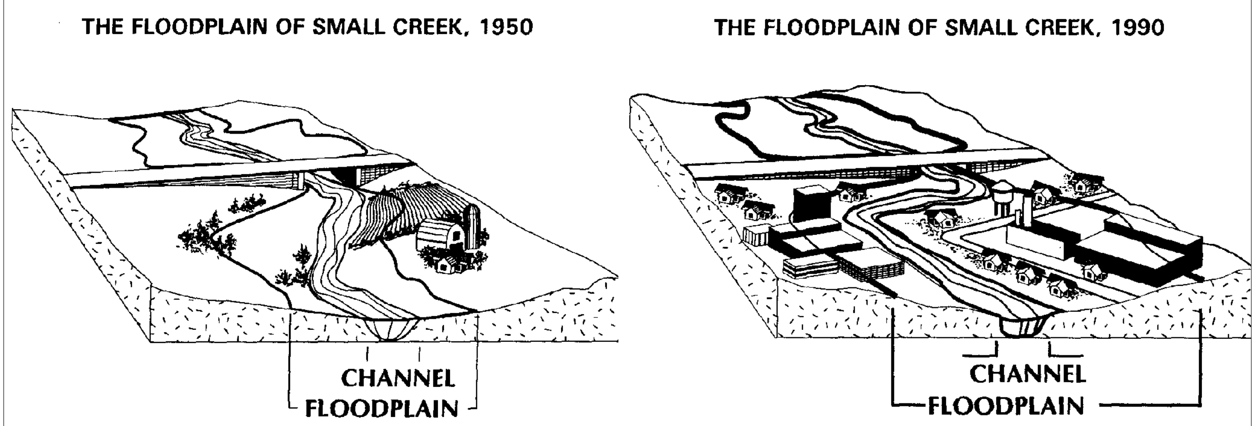

Figure 3-4. Schematic of Progressive Floodplain Development Source: ASFPM, 1997

Dams reduce the area and frequency of inundation on downstream floodplains by controlling the amount of water passing the dam location. The reduction in the area influenced by flooding causes a decrease in complex forms and beneficial functions in the ecosystem. Floodplain narrowing and conversion from wet to dry plant communities restricts the inundation of vegetated areas during normal seasonal high water periods. As a result of lowered nutrient and organic matter inputs from the reduction in flood extent, rearing habitats are diminished. Dams also tend to reduce the frequency and duration of bankfull discharge and restrict channel flow, leading to channel straightening and incision. Dams stop normal sediment transport in the downstream direction and erode the channel to bedrock below dams, eliminating spawning habitat.

Levees and **dikes** also tend to restrict the area of the floodplain exposed to flooding by constraining flows to the river channel, deepening the flow, and increasing flow velocities during flood stages. Typically, levees result in steep-sided trapezoidal channel cross-sections, rather than more natural compound channels with gentle bank slopes and flat-lying floodplain surfaces. The corresponding high depth to width ratio of leveed channels is inherently unstable during high flows. Additionally, as levees modify the natural floodplain, flow velocities increase, gravel patterns change, side channels and wetland areas diminish, and water temperatures increase. These modifications lower the quantity of vegetative cover, decreasing shallow water habitats.

Channelization simplifies the form of the channel and floodplain environment by straightening the channel or separating it from side channel features. This reduces habitat values and water quality downstream, increases flow velocity and often leads to a lowering of the stream bed. Hardening the banks of a river, through the use of rip rap or concrete, can result in increased downward scour of the river bed during flood flows. A deepened river channel may subsequently convey normal flows at lower water surface elevations and lead to the lowering of adjacent floodplain water table conditions, dramatically changing the extent and composition of riparian vegetation (Figure 3-5).

Large wood removal is a specific channelization technique that can drastically change water flow, bank

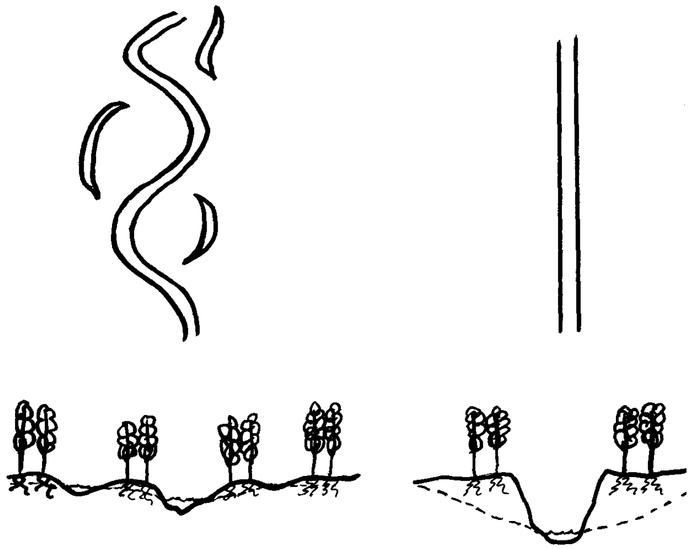

Figure 3-5. Floodplain Water Table Changes with Channelization Source: Malanson, 1993

erosion trends, and sediment deposition patterns. Large wood causes localized backwater flooding that leads to sediment accumulation and subsequent vegetative growth. Wood also absorbs flow energy, reduces stream velocities and creates secondary currents. These can create local scour pools that provide refuge and distribute gravel particles exposing sizes preferred by spawning salmon. Increased flow velocities caused by wood removal may accelerate channel instability and erosion damage to banks.

Gravel mining of the river channel and floodplain removes sediment delivered from the upland to lowland areas. When present, these sediments are reworked at high flows to create spawing gravels and land forms suitable for colonization by native plant species. The removal of gravels also causes an increase in stream power which can result in increased erosion.

Flooding was recognized by earlier cultures, and is still recognized in some countries, as a natural resource that can be managed effectively to fertilize floodplains. By diking, channelizing and making economic developments that were not adapted to the natural flood cycle, this benefit was often turned into a cost.
In addition to the physical impacts from human alteration of floodplains, the long-term economic benefits of floodplain development are questionable. Flood damage trends continue to increase, despite the national investment in flood control (Figure 3-6). In addition to the costs to construct flood control works, the long-term operation and maintenance costs of these facilities is increasing (Figure 3-7). Maintenance becomes more significant over time because most structural flood control works were designed with engineering criteria and assumptions that ignored natural river system processes.

As a result of recurring natural impacts and an increasing understanding for the economic reality of floodplain investments, human perceptions of the value and function of the river system continue to evolve. We are realizing that engineering solutions are costly, only protect local regions, and require a tradeoff between flood damage reduction and ecological resources

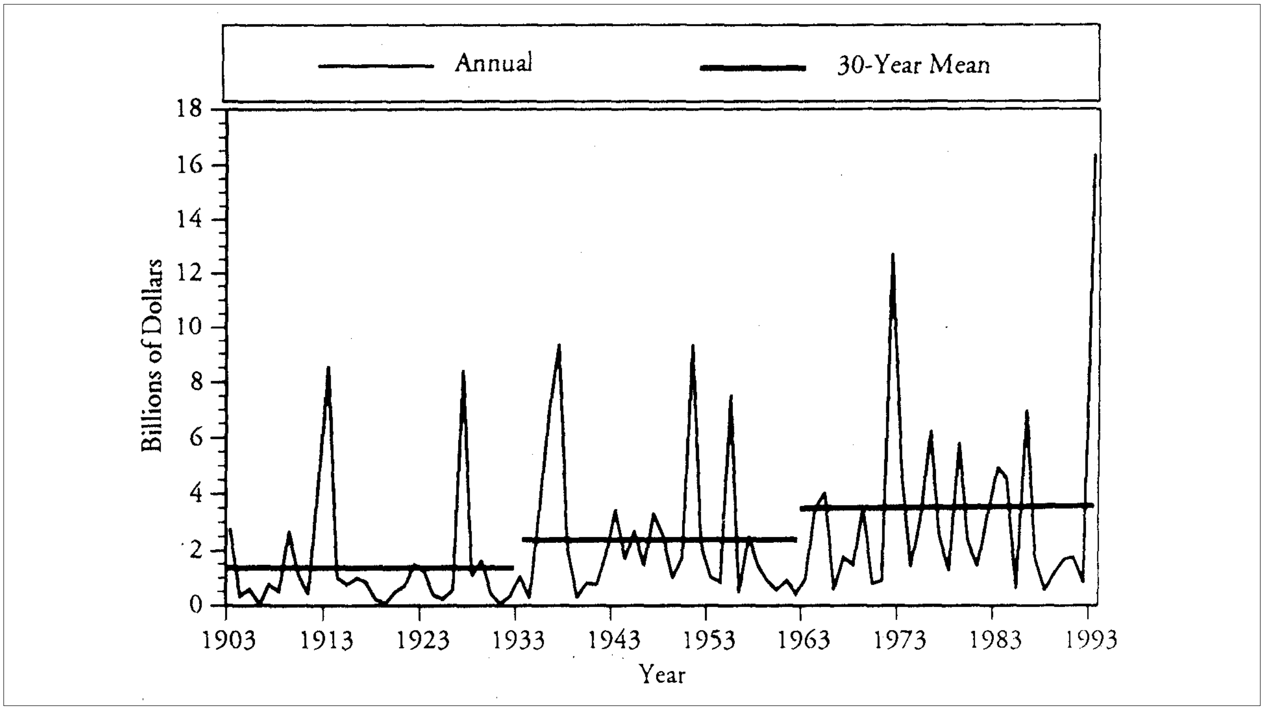

Figure 3-6. Flood Damage Trends for the United States. National average and 30-year mean flood damages, adjusted to 1993 dollars Source: Hey and Philippi, 1995

(Williams, 1994). Engineered solutions can also separate the community from the river, a valuable recreational and educational resource. Recent major floods and flood damages are prompting engineers to

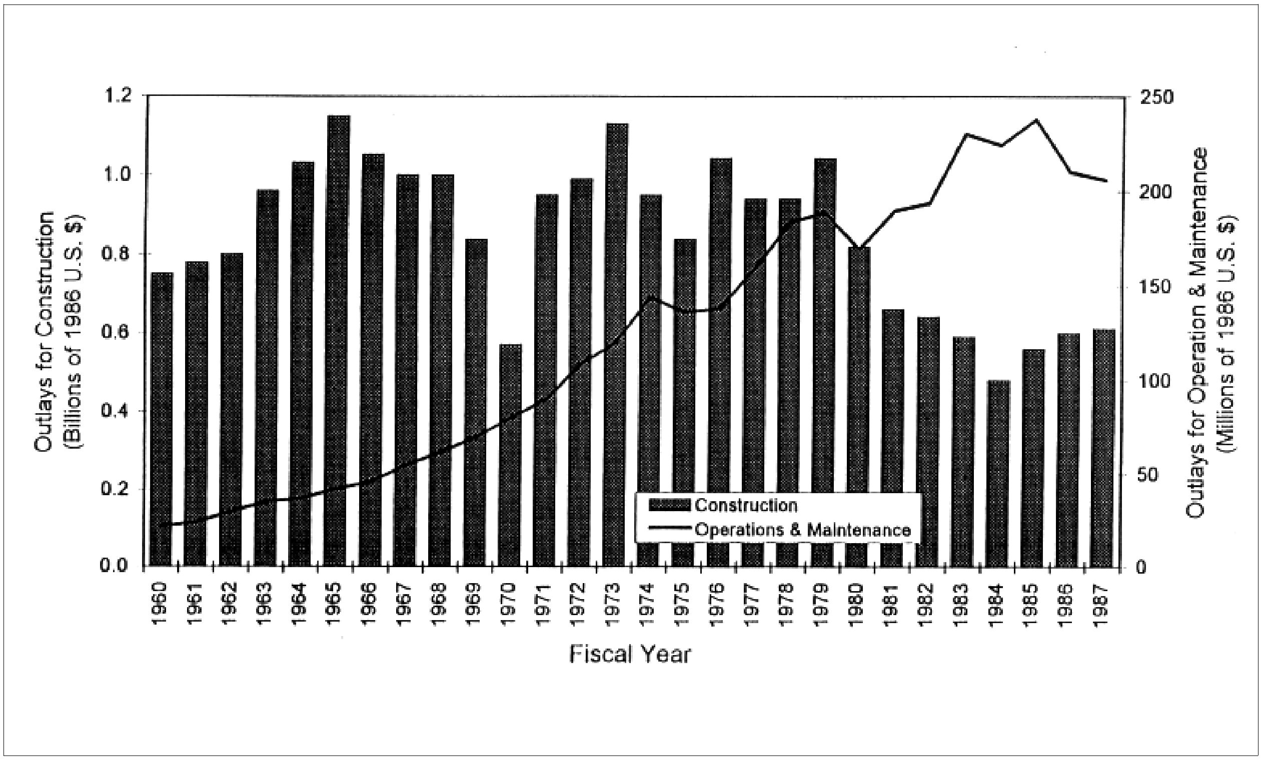

Figure 3-7. Flood Control Cost Trends in the United States Source: Rosen and Reuss, 1988

re-examine traditional methods of alleviating catastrophic flood hazards, and are causing us to rethink how we should handle floods in the future.

3.5 Trends in Floodplain Management

Our long-standing approaches to flood and fishery issues often work at cross-purposes to each other and end up achieving neither objective, i.e. increasing flood hazards and damages, as well as destroying salmon habitat. Many traditional approaches to river engineering are rooted in outdated economic or societal needs. Over the last century, societal goals for resource management have changed considerably from the time when Oregon's river engineering works were planned and implemented. Communities now value the environmental, recreational and aesthetic values rivers can provide, to a similar extent as the natural resources that have attracted us to rivers in the past. As a result, there is a need to plan for the long-term sustainable use of rivers rather than for the short-term exploitation of these systems that characterized the era of river engineering.

Unlike flood *control*, (quoted earlier) which relies solely on the use of structural measures—dikes, levees, dredging—to eliminate flooding, flood *management* includes more non-structural techniques to reduce flood hazards, such as land use planning, floodplain restoration, flood warning/emergency response, and public education. The premise of flood management is the understanding that not all flooding can be eliminated and that the goal should be to reduce flood risk to lives and property in a cost-effective manner (Williams, 1994).

Flood management also results from popular public opinion that wishes rivers to be more than just flood conveyance canals. Often, many objectives are specified at the start of a project. Effective "multi-objective" flood management is broader than a single focus on flood control, and requires the right mix of flow management, ecosystem management, and people management efforts (Figure 3-8) to effectively resolve flood problems and reduce the need for emergency flood response and recovery. Structural flood control measures remain important as elements in a river management strategy, but they are no longer the predominant element for meeting today's societal demand for a multi-objective focus.

Flood management also requires substituting "management" for "construction" as the most important activity for protecting floodplain investments. This in turn emphasizes the need for more sophisticated and effective maintenance, operations, flood warning, training, monitoring, and learning from experience to enable a cycle of constant improvements in river system management.

Trends in floodplain management are beginning to reflect the changing concerns of decision-makers. These include combinations of water resources, water quality, and flood defense objectives. Increasingly, these traditional objectives are leavened with consideration for fish and wildlife habitat and the importance of riparian areas for maintaining biodiversity. The historical focus on single-function management of river systems is gradually giving way to the multi-functional perspective, partly as a result of greater demands being placed on natural resources in general and water resources in particular.

Referring to the several routes of change towards a more sustainable water environment in Figure 3-9, there has been significant institutional and legislative change in the last two decades in the United States. For example, guidelines for FEMA mapping of floodplain lands has recently been expanded to allow consideration for migrating river channels and future

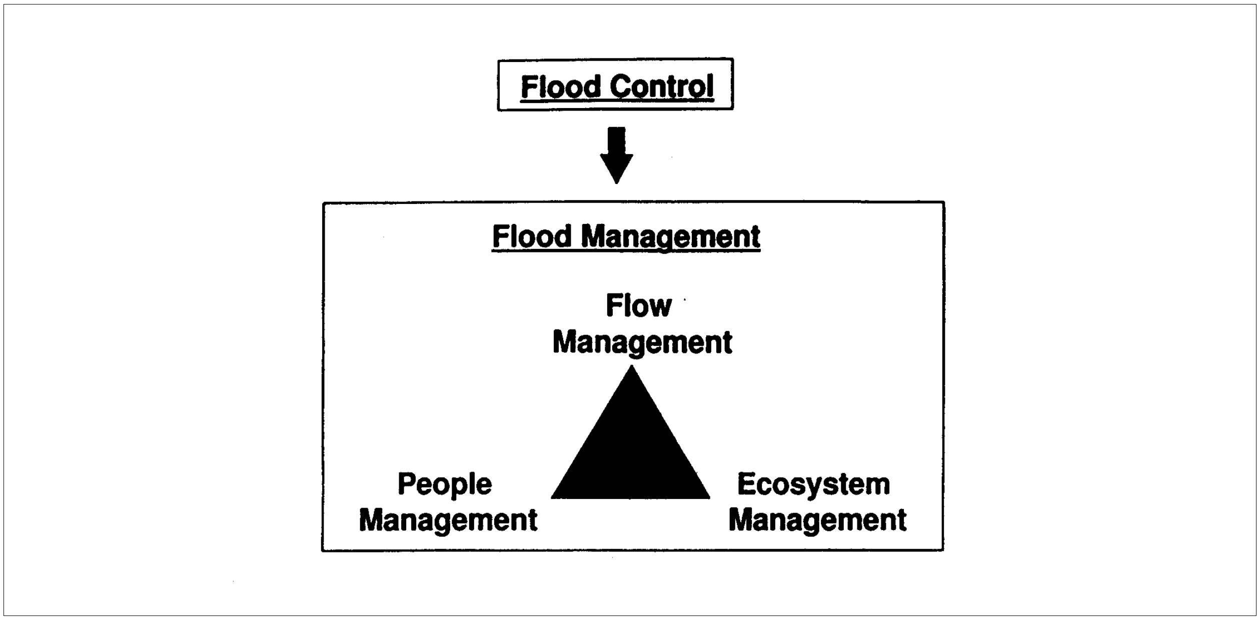

Figure 3-8. Policy Evolution from Flood Control to Flood Management. The evolution from “flood control” policy to “flood management” policy. Flood management policy requires an equivalent focus on managing ecosystems, flows, and people and their actions. Source: Haeuber and Michener, 1998

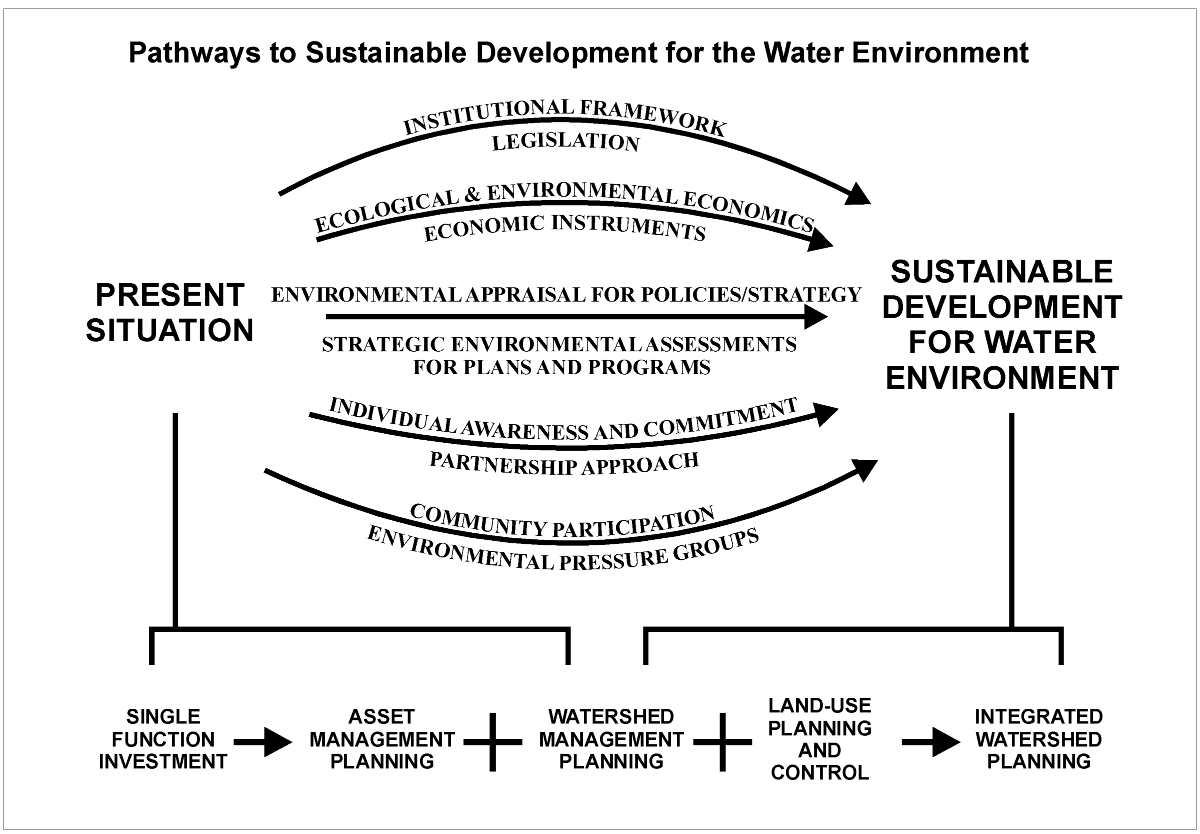

Figure 3-9. Pathways to Sustainable Development for the Water Environment

conditions hydrology. Also, US Army Corps of Engineers has a new mandate for ecological enhancement. The Endangered Species Act (ESA), with its requirement to preserve the habitat of threatened and endangered species, has far-reaching implications for integrated floodplain management. Virtually all aspects of the environment are impacted by the broad mandate of ESA. Thus, natural resource agencies such as the Division of State Lands in Oregon and federal agencies such as NMFS, USFW and FEMA, have emphasized the contributions of floodplains to healthy fish habitat. This habitat includes floodplain connectivity with streams, rivers, and sloughs as well as riparian habitat.

In the last few years, many federal agencies are coordinating their environmental review requirements to stimulate compliance with the ESA. For example, FEMA's current requirements for flood repair have been modified since the floods of 1996 to consider the integration of habitat restoration and ecosystem functionality.

Projects that use federal funds trigger a "federal nexus" which requires an Environmental Impact Assessment, including identification of cumulative impacts. Any development will require analysis of the hydrological regime, including impacts on flow regime, water balance, water quality and presence or absence of riparian vegetation. The EPA has developed guidelines which summarize the steps of the Cumulative Effects Analysis. They include:

1. Identify the significant cumulative effects associated with the proposed action and define the assessment goals.
2. Establish the geographic scope for the analysis.
3. Establish the time frame for the analysis.
4. Identify other actions affecting the resources, ecosystems, and human communities of concern.

Many communities are requiring a Cumulative Effects Analysis even when no federal funds are involved, because this methodology establishes benchmarks which can be used for mitigation.

In the last decade, there has been a marked increase in activity by individuals and non-governmental organizations to conserve and enhance rivers and floodplains. Many river groups have gained wide support from communities and regulatory agencies through awareness campaigns and political action. This development is especially strong in the U.S. where substantial funds have been raised from private donations, foundations, and government grant programs.

Efforts to improve the water quality of river systems are increasingly taking a close look at the degradation of floodplain lands. In recent decades, point-source pollution (pollution from pipe discharges and other discrete locations) was the focus of regulatory efforts, and this type of pollution has been substantially reduced. Attention has now turned to diffuse, or non-point, sources from agricultural and urban runoff. Floodplains are especially vulnerable to this form of pollution. Source control techniques are being applied as management strategies, to reduce the amount of non-point pollution generated, and the value of using vegetation to treat polluted runoff is now widely recognized and included in best management practices for surface water management.

At the same time, recent initiatives in assessing and improving the efficiency of industrial processes have shown that remarkable progress can be made in reducing water usage and improving the quality of waste streams, with payback periods of less than one year. The wider application of such investigations will do much to reduce the “ecological footprint” of industries situated in floodplains.

Economic incentives programs are now being used to assist the restoration of floodplains to more appropriate uses. This is fitting, since much of the deterioration of floodplains has been promoted by economic incentives for development that failed to take into account the intrinsic values of the floodplain itself. Pilot programs, such as one around the northern edge of Klamath Lake, have shown improved farming efficiency with the adoption of short-term rotational grazing, which allows economic wetland regeneration in floodplains. The principle underlying these improvements is that the natural resource is not exhausted before moving on – grass grazed to within two or three inches of the ground recovers much more quickly than grass grazed to its roots.

The success of community-based initiatives such as the Urban Streams Restoration Program in California, illustrates the need for community involvement in decision-making over floodplain management. With better understanding of the inter-connectivity of the river system, communities are coming together to agree on more sensible uses of the resource, acknowledging that the actions of upstream landowners can have profound effects on the livelihood of their downstream neighbors.

It is worthwhile to note that despite policy-level and grass roots movement toward environmentally sensitive floodplain management and flood response, significant opportunities associated with the 1996 flood event in Oregon were lost simply because appropriate integrated river management strategies were not yet in place. For example, under post-flood emergency conditions, and without an alternative plan for flood response, flood control facilities and buildings were in many cases rebuilt to pre-flood conditions, where many might have been reconsidered in light of newer priorities. This illustrates that implementation of sound floodplain management is best done sooner rather than later, i.e. before, rather than after, the next major flood event.

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CHAPTER 4: Regional Overview of Flood Risk & Salmon Distribution

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4. Regional Overview of Flood Risk and Salmon Distribution

As wirh other states in the U. S., Oregon has seen flood damages steadily increase while the natural benefits of functioning floodplains have decreased. The recent listing of a number of anadromous fish species in Oregon is a significant indicator of floodplain degradation. Oregon has an opportunity to manage its floodplains in a way that reduces flood damages while preserving and even restoring the habitats needed to support anadromous fish populations. However, not all of the state's floodplains have equal potential. Some floodplains are not significant to anadromous fish while others don't have costly damage problems. In the western part of the state, high rainfall and significant human population centers combined with a dense network of streams that drain to the ocean increase the coincidence of fish habitat and flood damages. The Tillamook basin is home to a significant number of anadromous fish species and has had the highest flood damages in the state. This makes the Tillamook basin a potential testing ground for an Integrated River Management Strategy (IRMS) that combines goals for flood damage reduction with aquatic habitat preservation and restoration. This section characterizes the significance of Oregon floodplains for flood risk and fish habitat and demonstrates a rational for locating areas within the state where an IRMS would be effective.

4.1 Oregon Floodplains

Oregon's terrain varies dramatically and so do its floodplains. This diversity enhances the state's capacity to support a wide variety of terrestrial and aquatic species. Flooding is an ephemeral process with much uncertainty associated with the magnitude, frequency and spatial extent of the resultant floodplain on the landscape. Because of this uncertainty, several methods have been used to define and characterize the flood process. In order to broadly characterize floodplains at the state level for this study, geomorphic floodplains (floodplains defined by soils that have floodprone characteristics) were used. The geomorphic floodplain data layer was combined with other state-wide GIS data to perform a strategic spatial analysis of the floodplain characteristics in Oregon.

4.2 Regulatory Floodplains

Probably the most familiar floodplain definition to many people is the regulatory 100-year floodplain delineated by the Federal Emergency Management Agency (FEMA) for use in the National Flood Insurance Program (NFIP). The NFIP was created to encourage the adoption of floodplain development guidelines within FEMA-designated flood hazard zones by providing flood insurance to communities that adopted those guidelines. The FEMA 100-year floodplain represents a theoretical flood hazard area that is estimated to result from the occurrence of the "100-year flood", a flood that has a 1-percent chance of happening in any given year. The 100-year flood has a statistical value derived from historic streamflow data and the hydrologic characteristics of a particular watershed.

Since the regulatory 100-year floodplain data were developed as a part of the NFIP, the mapping of the regulatory 100-year floodplain is limited to urban or developing areas. Consequently, large portions of south, southeast and southwest Oregon are not covered by FEMA floodplain data. Lack of coverage makes it impossible to do state-scale analysis using FEMA-defined floodplains (Figure 4-1).

4.3 Geomorphic Floodplains

Geomorphic floodplains are defined by soils subject to flooding. This information is derived from the State Soil Geographic Data Base (STATSGO) (Figure 4-2). STATSGO soils data are derived from 1:250,000 generalized soils maps and are available only in digital format. These data are compiled by generalizing more detailed soil survey maps which are based on field observations. STATSGO should be used for state or regional resource planning and should not be used for interpretation at the county level (U. S. Department of Agriculture, 1991).

The STATSGO data include 217 map units. Each map unit represents a group of soils that have been developed from similar geologic materials on similar landscapes and in similar climatic regions (Thorson *et al.,* 1996). Geomorphic floodplains are delineated based on map units where ten percent or more of the soils comprising each individual map unit are subject to rare, occasional or frequent flooding. Rare flooding is defined as flooding that is unlikely but possible under unusual weather conditions, with a 1 to 5 percent chance of flooding in any year. These statistics are similar to the familiar FEMA regulatory floodplains that also delineate land areas that have a 1-percent probability of flooding in any year. Therefore, the geomorphic floodplains have been used in the remainder of this discussion because they represent a natural expression of a 100-year flood event and they are mapped for the entire state.

4.4 Flood Damages

A simple way to link geomorphic floodplains to flood events is to map them with NFIP claims. These claims do not provide a complete picture of flood damage in the State as NFIP claims only represent damages to structures in urban areas. There are different program that cover damages to equipment, crops, and livestock associated with agriculture.

The NFIP claims mapped for the State of Oregon in Figure 4-3 are all claims filed between 1977 and 1998 for which a location was available. Most of the people in Oregon live west of the Cascade Mountains in the Willamette Valley and most of the rainfall in the State falls in the Coast Range. Not surprisingly, a majority of the NFIP claims are located in these areas.

4.5 1996 Floods

Some of the most damaging floods in Oregon occurred in February of 1996. The combination of rain and warm temperatures from a series of intense surges of tropical moisture, preceded by freezing temperatures and a deep snowpack created the extreme flood situation. These 'rain on snow' events are associated with many of Oregon's most damaging floods.
By January 31, 1996, the average snowpack in the Oregon Cascades was about 115-percent of normal and in Washington about 130-percent of normal. Low-elevation snow was reported at 500- to 600-percent of normal, and there was snow on the Willamette Valley floor. There was an intense cold spell the week of January 29th and on February 3rd a moderate storm dropped rain on frozen ground.

Most basins of Northwest Oregon and Southwest Washington had received precipitation for the water year at least 125-percent of normal (some as high as 200-percent) which saturated the soils and brought up groundwater levels. Four-day totals of precipitation exceeded previous records at many locations in the states of Oregon and Washington, Astoria (8.9 in), Corvallis (8.1 in), and Oregon City (7.5 in). The spatial

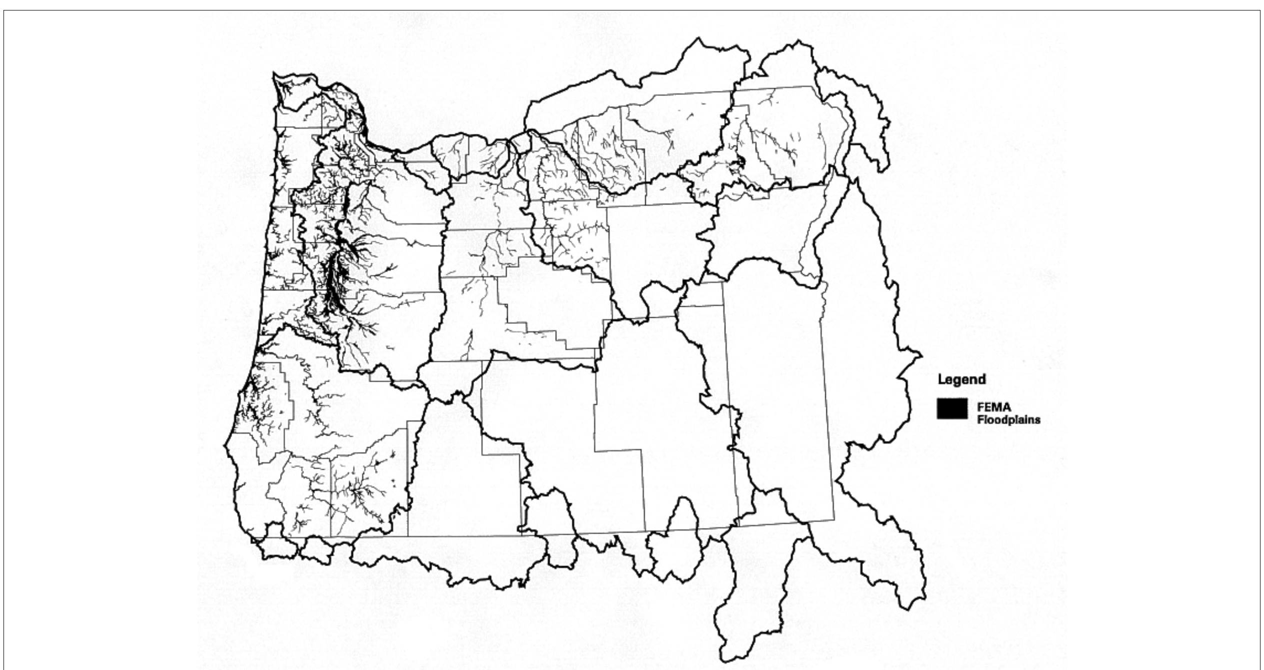

Figure 4-1. Oregon Regulatory Floodplains

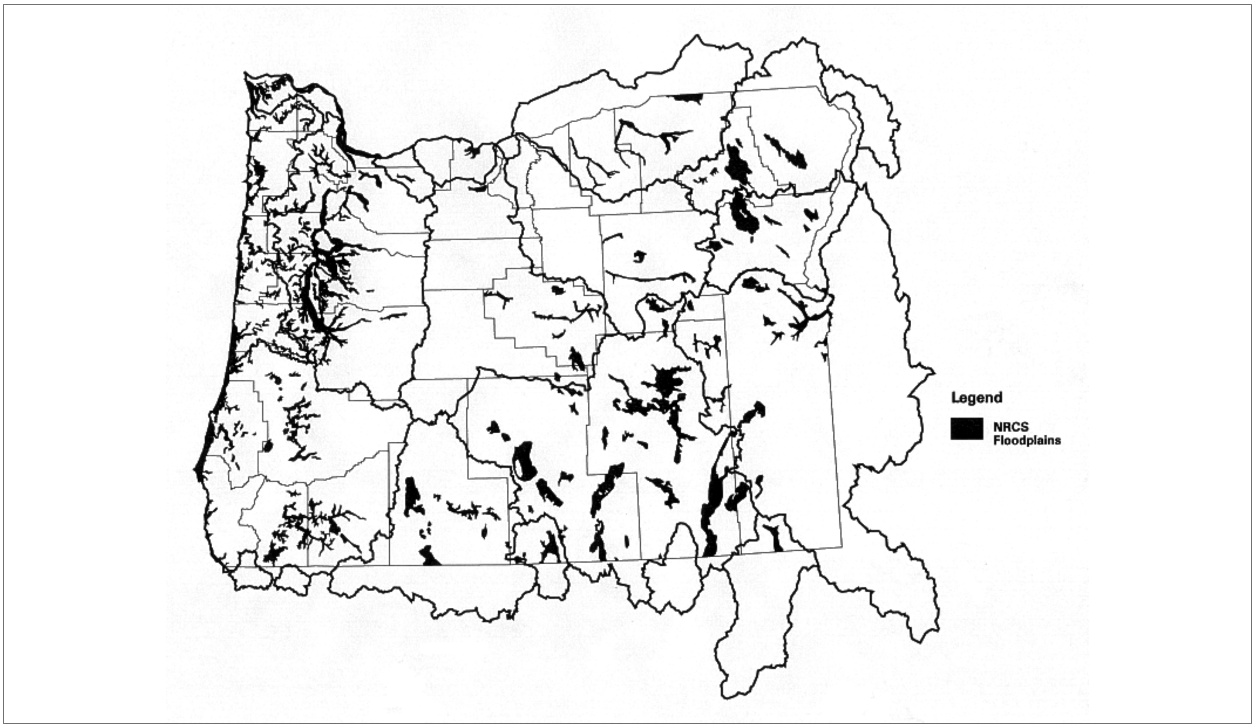

Figure 4-2. Oregon Geomorphic Floodplains

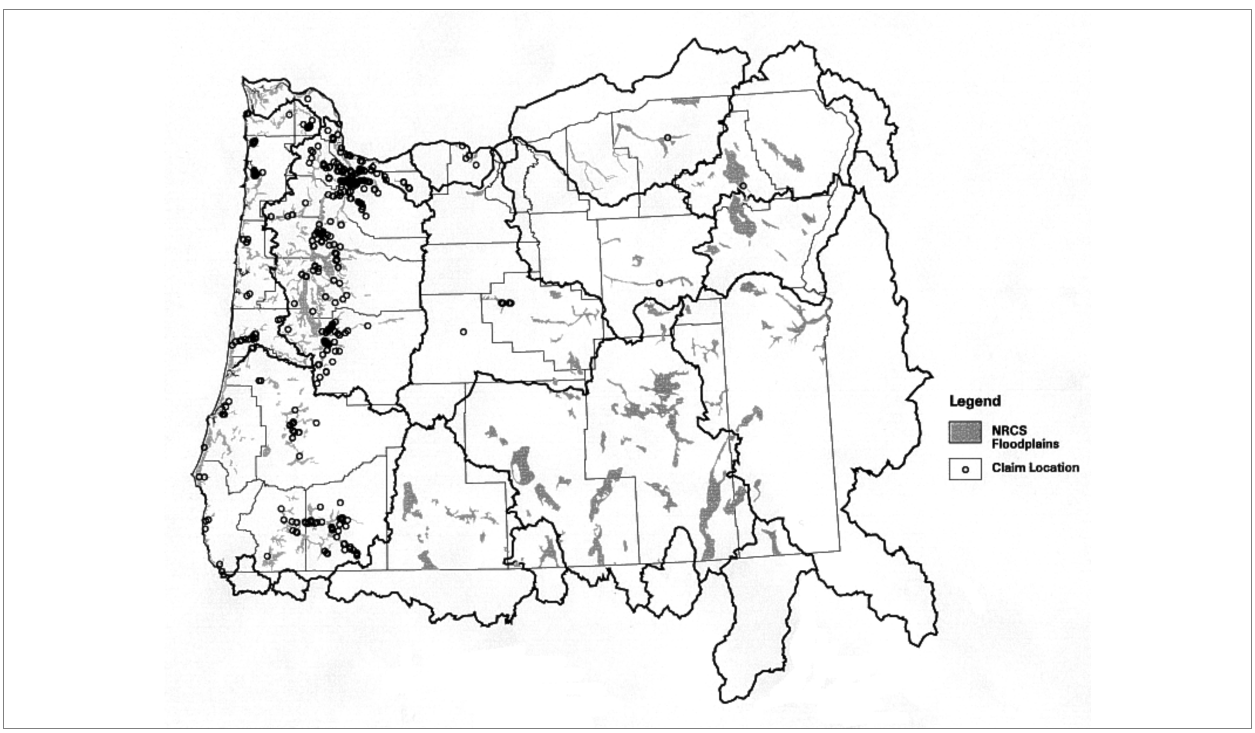

Figure 4-3. NFIP Claims between 1977 and 1998

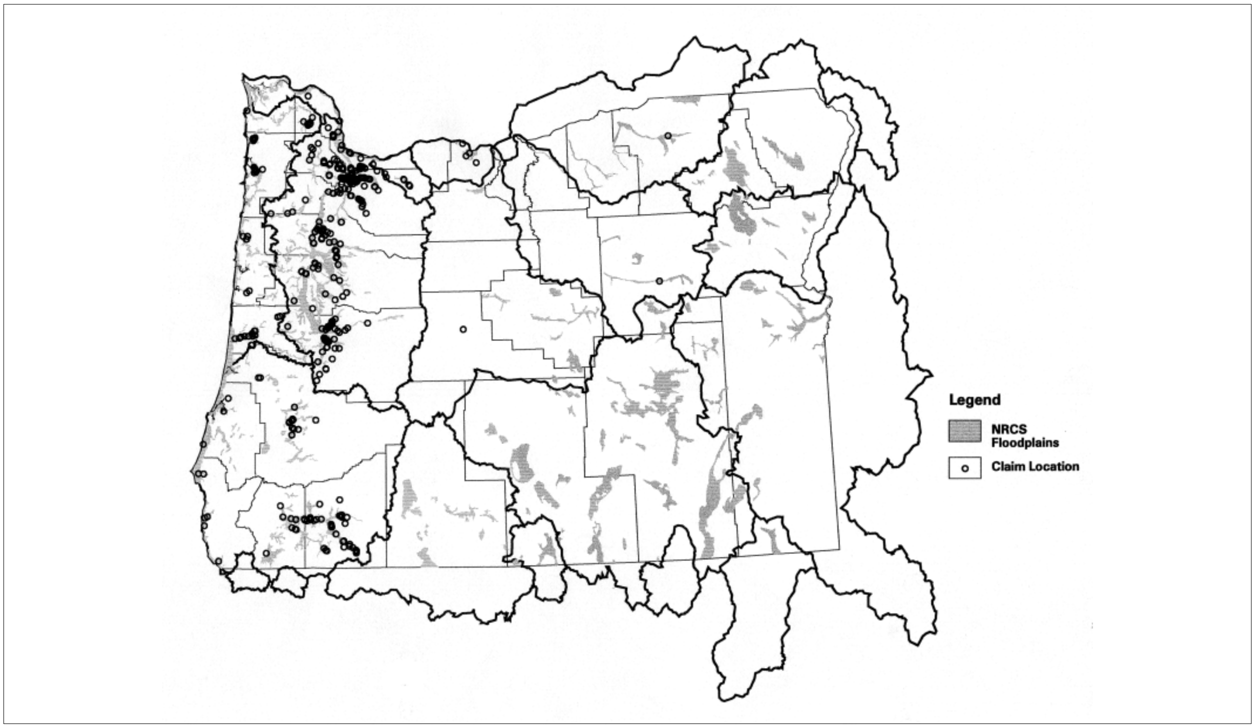

Figure 4-4. NFIP Claims February 1996 to February 1997

distribution of claims the year following the February 1996 floods is illustrated in Figure 4-4.

Of all Oregon counties affected by the 1996 floods, Tillamook County sustained the highest amount of damage (Figure 4-5). The county also had the highest amount of damage as a percentage of the annual budget (Figure 4-6). Total February 1996 flood damages were estimated at $53 million. Numerous flood response permits were applied for in Tillamook County and statewide.

The distribution of flood damage claims is a reasonable proxy for the distribution of flood control activity. As discussed earlier, these projects take a number of forms including dams, levees, dikes, and channelization each of which has negative effects on aquatic habitat.

4.6 Salmon Distribution

In light of this connection between flood control projects and the degradation of aquatic habitat, it is useful to characterize the relationship of Oregon's floodplains to anadromous fish populations. By definition, anadromous fish spend part of their lives in the ocean, but not all of Oregon's floodplains are hydrologically connected to the ocean.

Figures 3-7 thru 3-11 show the geomorphic floodplain data layer mapped with the streams utilized by coho, chum, spring chinook, fall chinook, and winter steelhead. Each of these species occurs and is listed in the Tillamook basin. The shaded drainage basin in south central Oregon represents land area not tributary

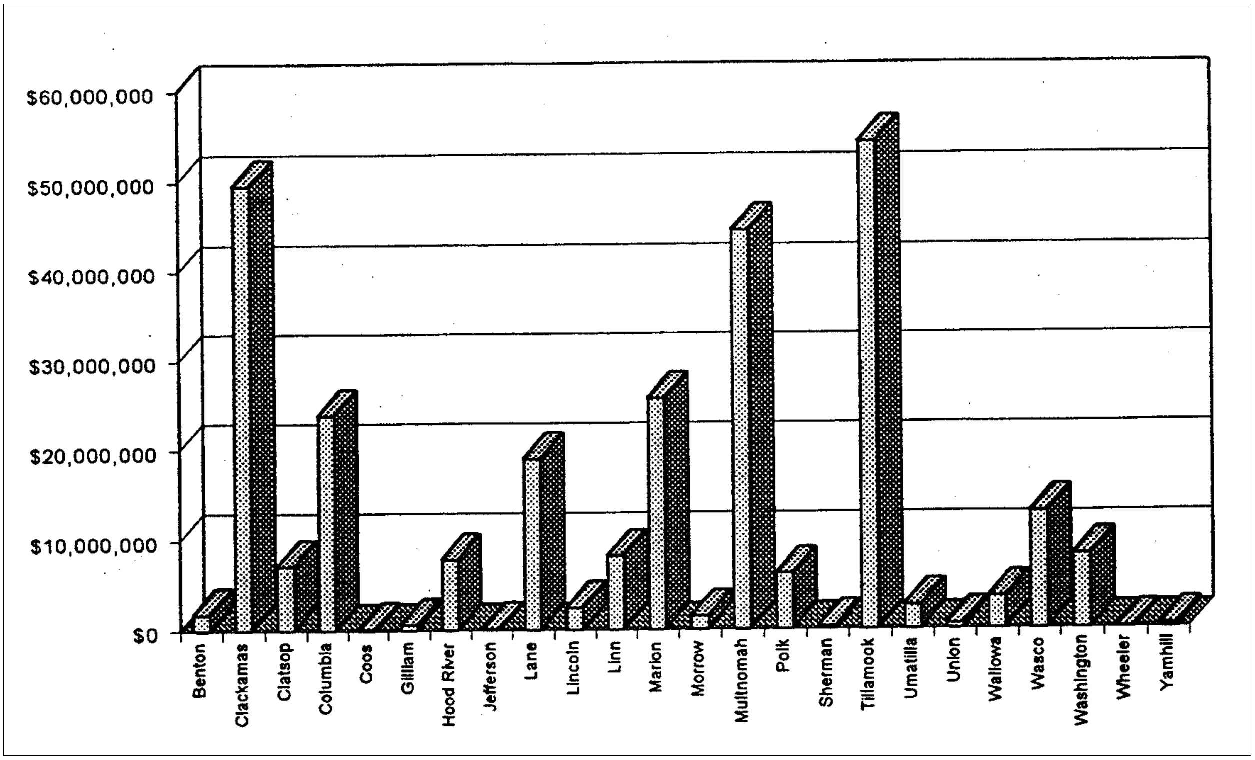

Figure 4-5. Damage by County Source: Interagency Hazard Mitigation Team Report, 1996

to the ocean and, therefore, not part of the distribution of anadromous salmon. The spatial distribution of these species is heavily weighted toward coastal areas and the Willamette basin. High precipitation and dense conifer vegetation combine with good access to ocean habitats in these areas to make them attractive to anadromous fish. A visual comparison of the State's NFIP floodplains (Figure 4-1) and the combined distribution of the five salmon species (Figure 4-12), shows how ubiquitous salmon are to regulated waterways.

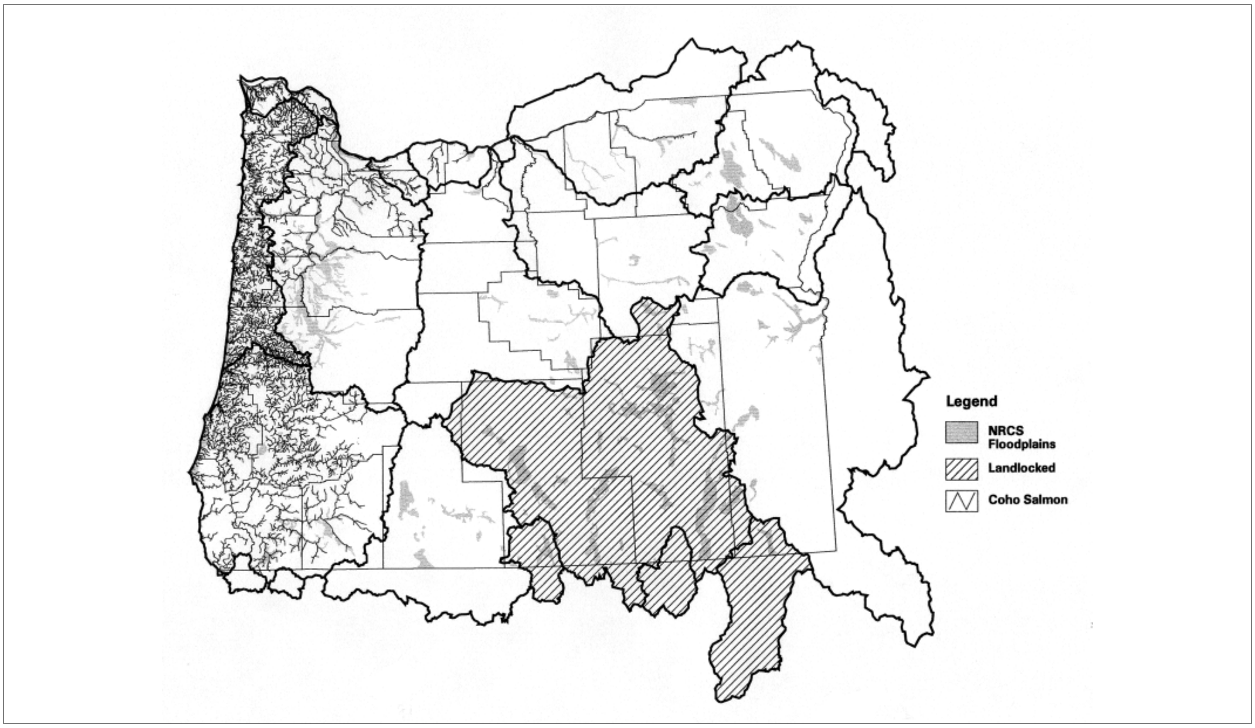

Figure 4-7. Coho Salmon Distribution

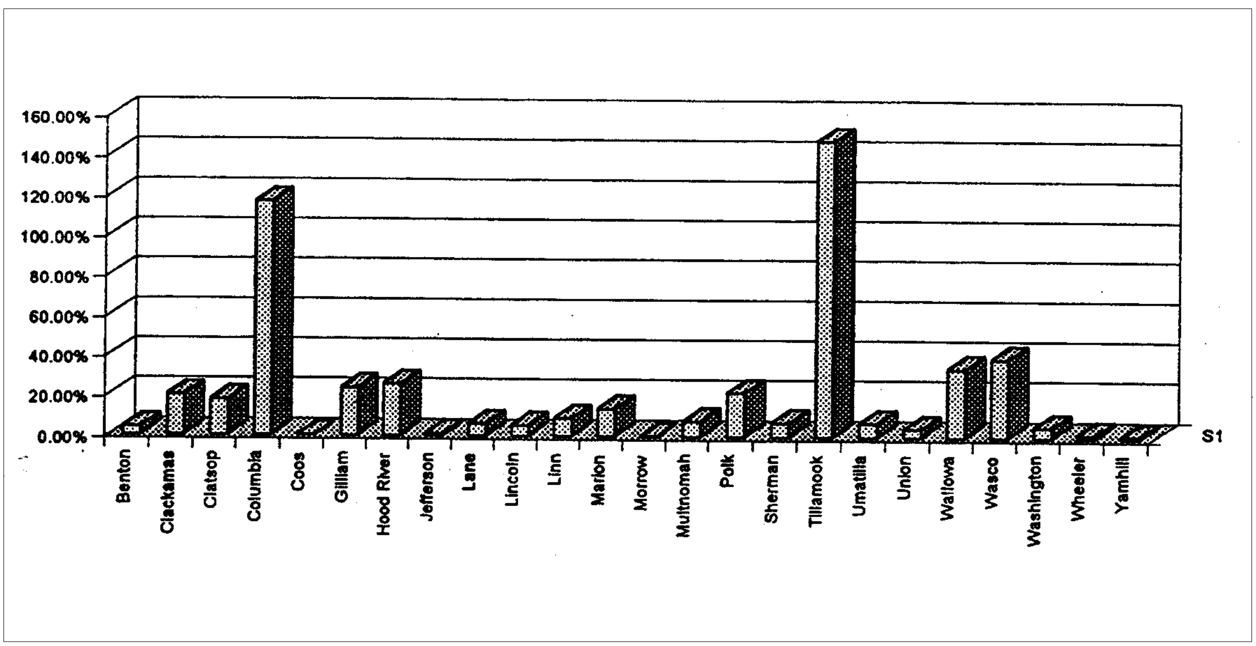

Figure 4-6. Damage as Percent of Annual Budget Source: Interagency Hazard Mitigation Team Report, 1996

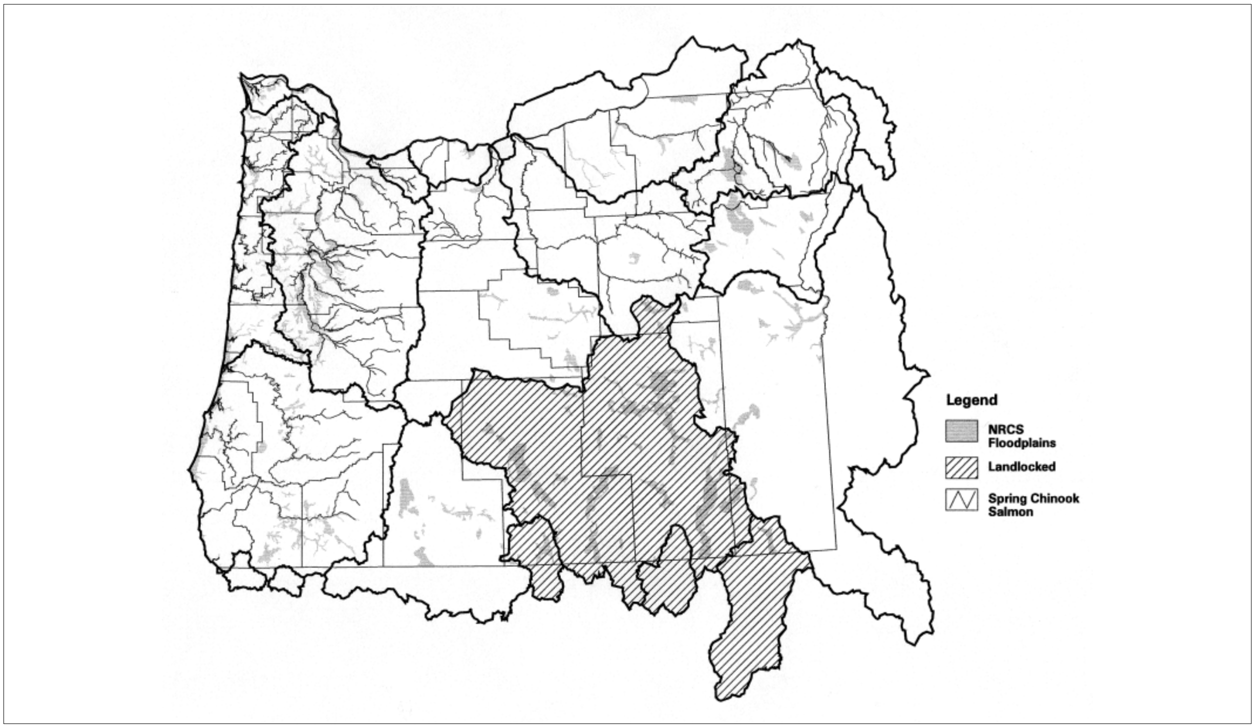

Figure 4-8. Spring Chinook Distribution

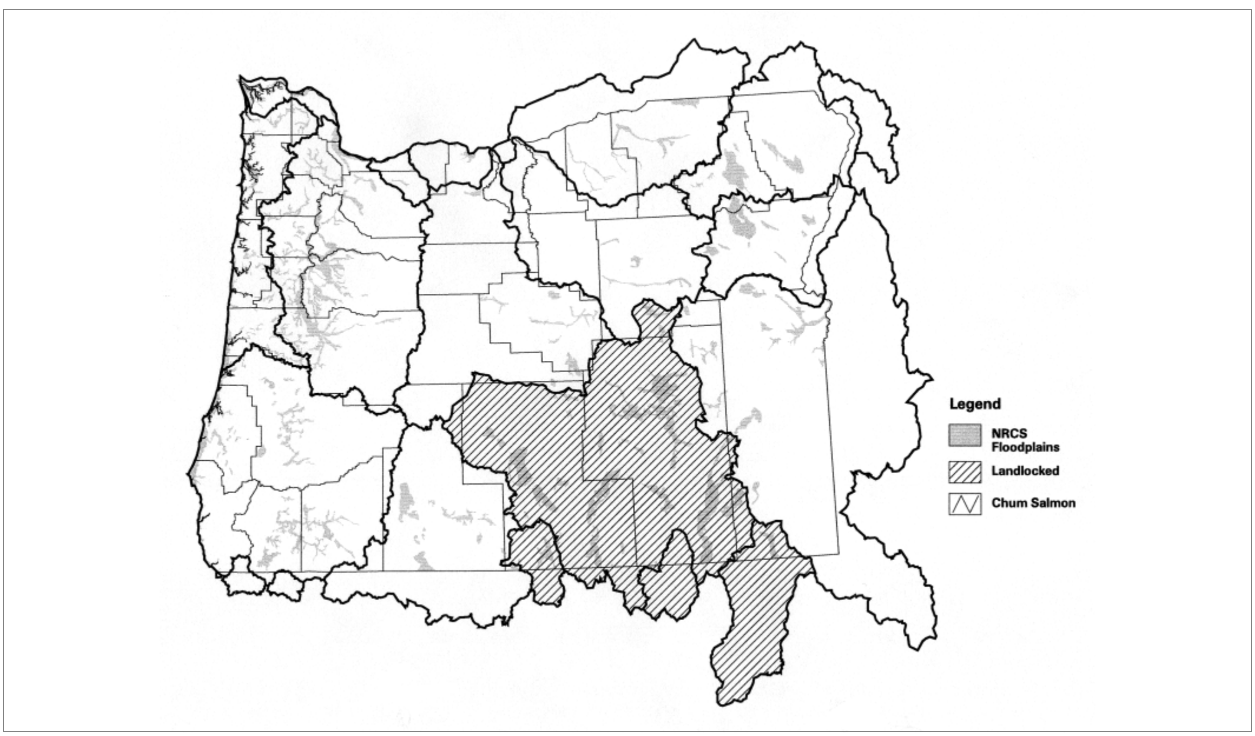

Figure 4-9. Chum Salmon Distribution

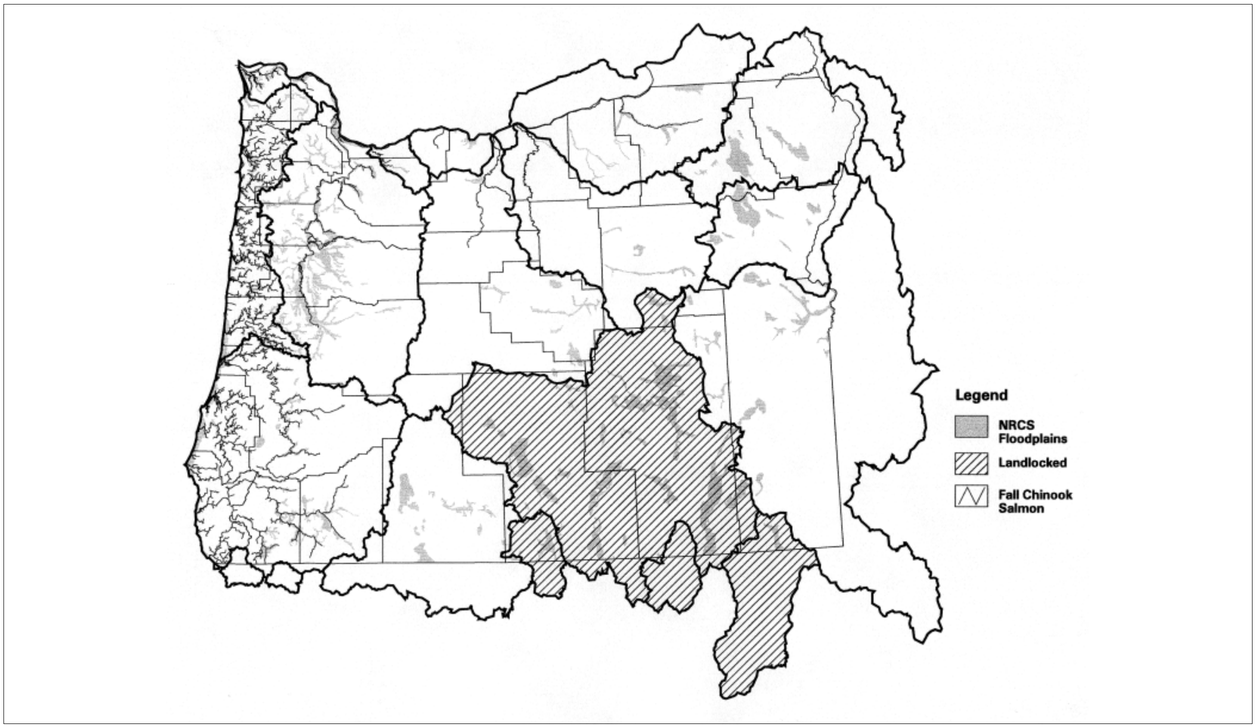

Figure 4-10. Fall Chinook Distribution

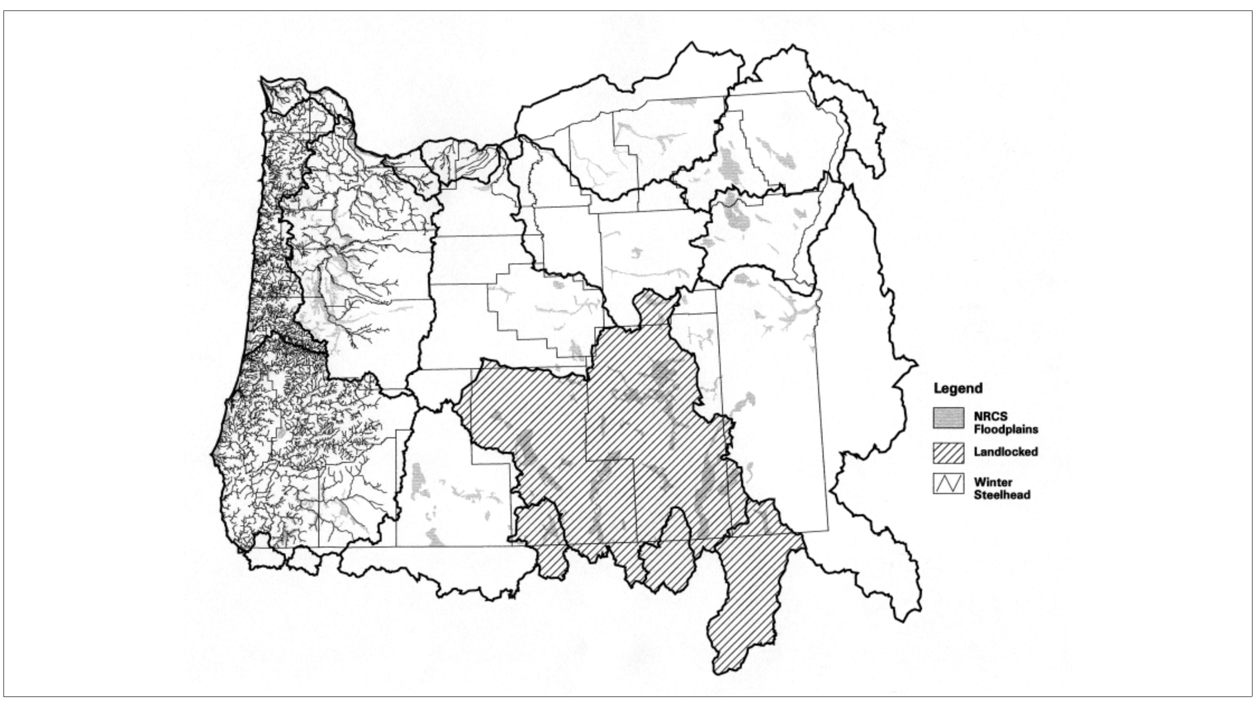

Figure 4-11. Winter Steelhead Distribution

4.7 Ecoregions

The appropriateness of a floodplain management strategy is dictated by environmental conditions. Ecoregions are a scientifically accepted way to divide the landscape based on environmental conditions. Ecoregions, as defined by the USEPA, are distinguished based on precipitation patterns and amounts; physiography, geology, soils, and potential vegetation; land use and land cover. As such, they describe areas with similar ecological communities. Because of this commonality it is not surprising that species of salmon favor certain ecoregions as habitat.

The Coast Range ecoregion (Figure 4-13) includes parts of western Washington, Oregon, and northwestern California. It can generally be divided into three zones: coastal lowlands, coastal uplands, and a number of montane zones that include volcanic and mid-coastal sedimentary areas. The montane areas occur above 500-feet and are generally steep and covered with conifer forest. They vary from highly erosive soils that are prone to mass movement to relatively stable rock. Coastal uplands are marine influenced humid area between 300 and 500-feet that corresponds to the historic distribution of Sitka spruce forest. This area gradually transitions to the coastal lowland zone which includes marshes, lakes, and dune areas (Pater *et al.*, 1997). The region as a whole receives a tremendous amount of precipitation and has relatively stable temperatures due to marine influence.

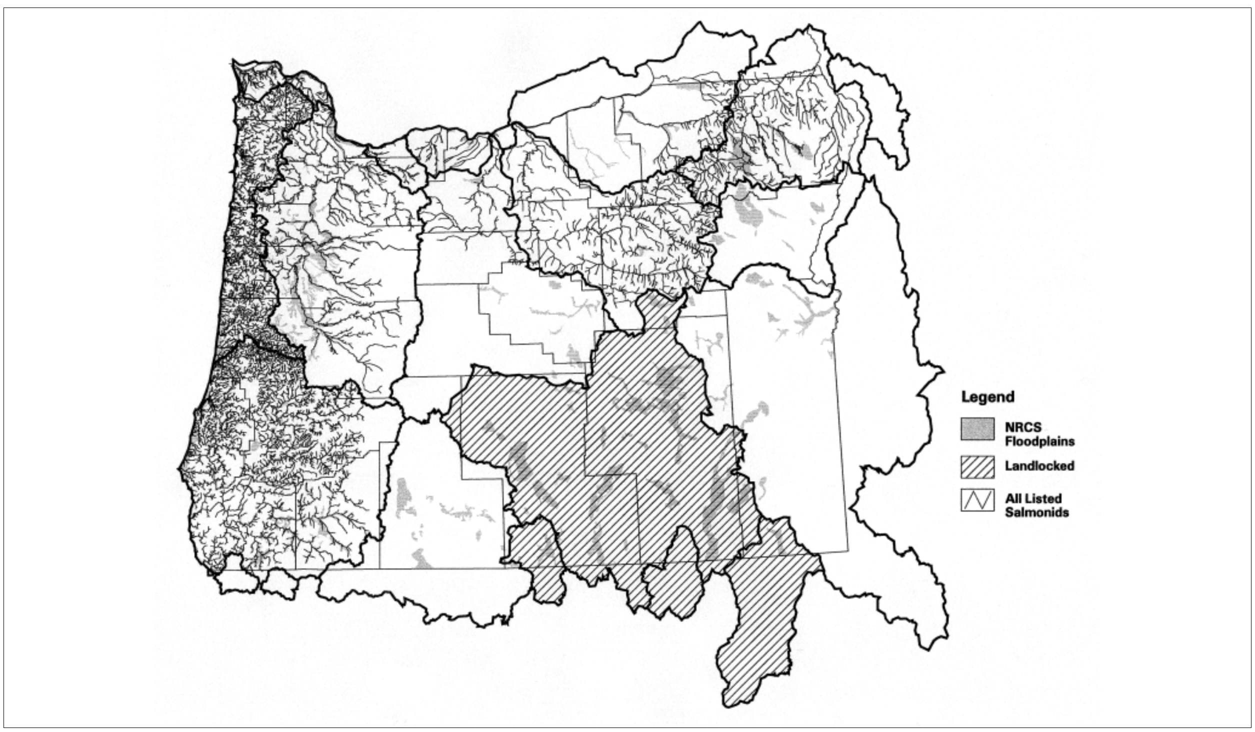

Figure 4-12. Combined Distribution of all Five Species

The environmental qualities of the region make it ideal for timber, dairy, fishing and recreation uses. It is, therefore, understandable that conflicts between these uses and habitats occur within this ecoregion.

A comparison of the distribution of NFIP claims following the 1996 floods and the location of streams significant to all five species of salmon within the coastal ecoregion graphically shows the significance of Tillamook Bay within this region (Figure 4-14), and the need for complementary management of fisheries resources and flood risk reduction.

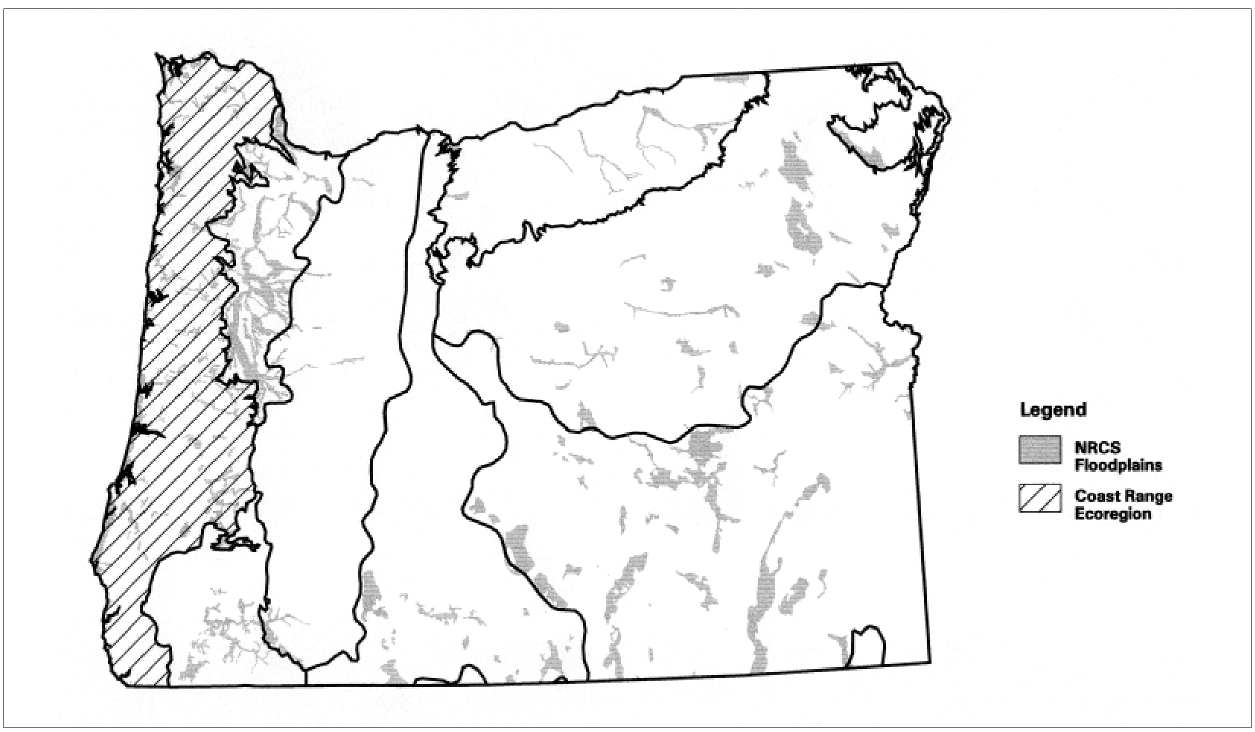

Figure 4-13. Ecoregions of Oregon

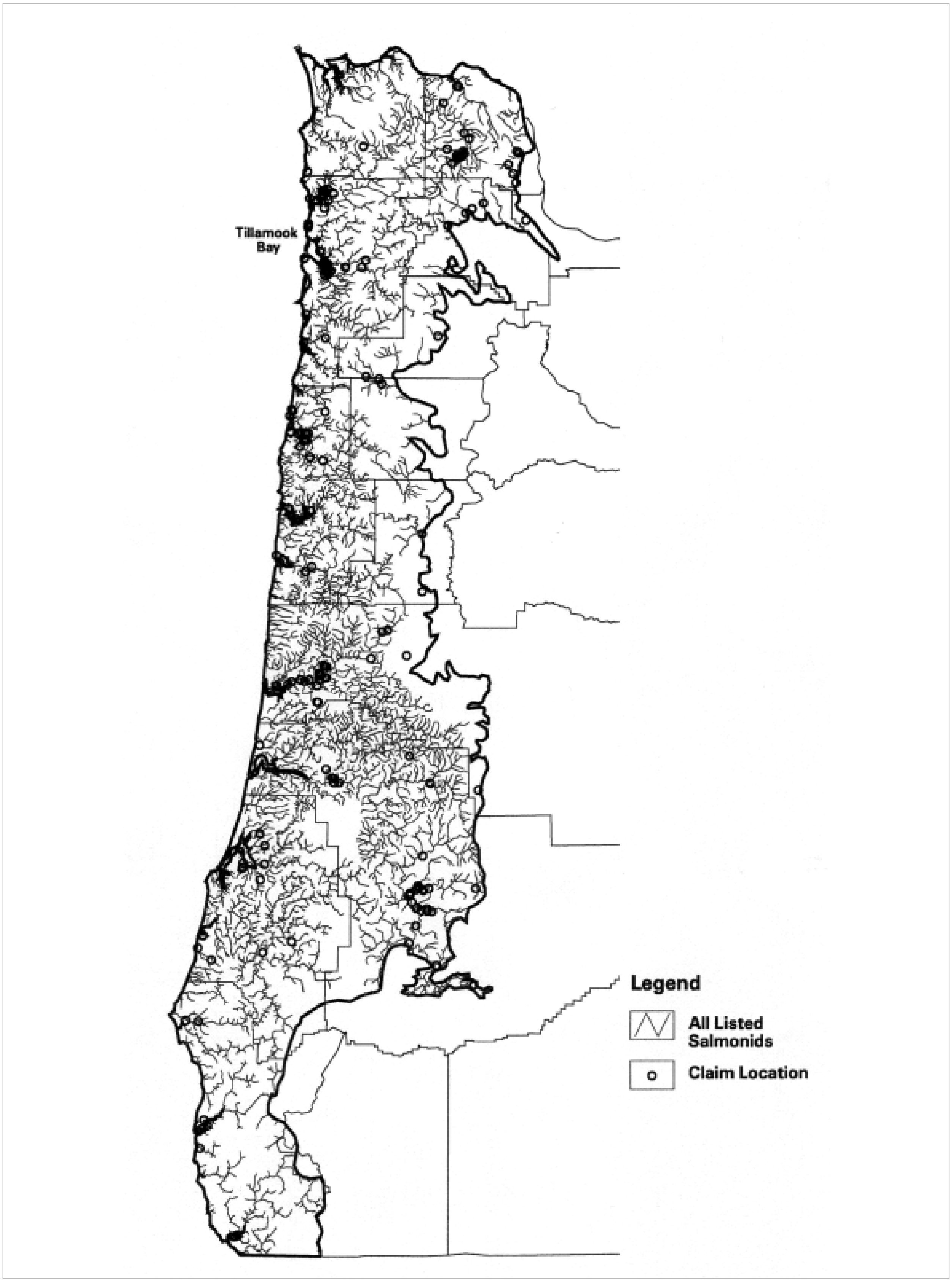

Figure 4-14. Oregon Coast Ecoregion with NFIP Claims and Salmon Distribution

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CHAPTER 5: History and Effects of Human Interventions in the Tillamook Basin

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5. History and Effects of Human Interventions in the Tillamook Basin

Streams, rivers, and estuarine areas within the Tillamook Bay basin historically provided diverse habitats for a variety of aquatic, semi-aquatic, and terrestrial species of plants and animals. Aquatic systems within the Tillamook Bay basin were historically some of the most biologically productive on the Oregon Coast, and remain so for some species of fish and shellfish. The basin is characterized by streams and rivers that flow from steep and erosion-prone uplands, through extensive lowlands surrounding much of Tillamook Bay, and into a drowned-river estuary (the bay itself) that is one of the largest in Oregon (Bottom *et al.*, 1979). Environmental conditions within the basin, and patterns of change in these conditions over time, have been described in detail by Coulton *et al.* (1996a) and TBNEP (1998a). Overall, the basin is typical of many in the Pacific Northwest in that important natural features, including streams, rivers, riparian areas, and the estuary, are exhibiting multiple problems attributed to land use practices (TBNEP, 1998a). Of particular concern to the basin's residents are the sedimentation of lowland rivers, reduced water quality, declining populations of multiple salmon species, and increasing flood damages to both public and private property within floodplain areas.

5.1 Historic Landscape Conditions

The present landscape conditions and the influences of human actions in the Tillamook Bay Basin, can be placed in a better context by reflecting on the history and evolution of the forests and floodplains of the region, the role of natural disturbances in them, and how their interactions support salmon.

5.1.1 Landscape Habitats

▪ *Upland Forests*

Waring and Franklin (1979) described the historical and climatological origins of Pacific Northwest coniferous forests. According to these authors, these forests were unmatched in terms of the size and longevity of individual trees and accumulation of biomass. Conifers account for a thousand times more biomass than hardwoods in the Pacific Northwest, an enormous divergence from the hardwood or mixed forests typical of the northern temperate zone.

Conifer dominance in the Pacific Northwest dates back 12 to 18 million years to the late Miocene (Waring and Franklin, 1979). During this period, there was a high rate of hardwood extinction in the Pacific Northwest and unbroken conifer forests spread from Oregon to Alaska. By the early Pleistocene (1.5 million years ago) the native flora of the Pacific Northwest was essentially the same as today (Waring and Franklin,1979).

At the end of the last glacial period, Sitka spruce (*Picea sitkensis*) and lodgepole pine (*Pinus contorta*) dominated the forests west of the Cascade Mountains. These forests persisted roughly from 15,000 to 12,000 years before present. Toward the end of that period, western hemlock (*Tsuga heterophylla*) and Douglas fir (*Pseudotsuga menziesii*) became more prominent in the region. By 10,000 years ago the dominant species of this region were western hemlock and Douglas fir, with red alder (*Alnus rubra*) common in riparian zones. The period from 10,000 to 7,000 years ago was warmer and drier than today. Fires were more frequent and forests were predominantly Douglas fir. Over the past 7,000 years fires have been less frequent, allowing for an increase in the abundance of western hemlock and western red cedar (*Thuja plicata*) and leading to a decrease in Douglas fir which is less-shade tolerant.

The climate of the western Pacific Northwest is characterized by wet, mild winters and warm, dry summers and is a principal factor favoring conifers. Generally less than 10-percent of the annual precipitation falls during the summer months. In the dormant season precipitation is heavy, with daytime temperatures usually above or near freezing. This is strikingly different from most other temperate forests where precipitation is distributed much more evenly through the year.

▪ *Lowland Forests and Wetlands*

The lowland areas of the coast were characterized by wetlands, wet and dry prairie, and riparian forest crossed by the main channels and side channels of rivers. The native plant communities found in these areas evolved within a cycle of annual high water and periodic flooding. Flood tolerant species are very resilient and respond well to disturbance. For this reason, riparian areas are one of the most highly productive ecosystems.

▪ *Estuaries*

The Tillamook Bay estuary is a relatively shallow, depositional environment whose bathymetry reflects the interaction of underlying geologic features, sedimentation, subsidence processes, and tidal action. The earliest bathymetric survey of the bay, in 1867, showed it to have complex features, numerous wide channels, and deep scour holes. Original maps and field notes from early land surveys of lowlands adjacent to the bay clearly indicate the presence of abundant and often sinuous tidal sloughs surrounded by varied marshes (Coulton *et al.*, 1996a). These sloughs, and particularly shallower portions of the bay near the mouths of the larger rivers, were areas where substantial quantities of large wood tended to accumulate (Maser and Sedell, 1994).

5.1.2 Landscape Processes

■ ***Wildfires and Landslides***

Within the forested upland areas, high-quality habitats in streams and rivers were created and maintained through cycles of natural disturbance and recovery. Recent research suggests that along the northern Oregon Coast, these cycles were generally driven by large, catastrophic wildfires with a mean return interval exceeding several hundred years (Benda, 1994) followed by long periods of natural recovery punctuated by flood events. The fires probably covered areas of entire forested watersheds, causing over 70 percent mortality and leaving up to 30 percent of the area as unburned islands (Ward, 1977). Resultant landslides introduced substantial volumes of sediment and large woody material to stream channels, legacy effects that reset the affected areas for another cycle of recovery (Reeves *et al.*, 1995). Over time these materials were transported downstream via the river system enriching the lowland ecosystem.

■ ***Floods and Fluvial Processes***

Under natural conditions lowland streams were relatively sinuous, complex (i.e., with diverse hydraulic conditions and variable numbers of active channels), and characterized by abundant amounts of large wood. This large wood, interacting with periodic flood flows, played an integral role in creating and maintaining channel complexity. The large wood frequently formed massive drift jams in the lower reaches of the larger rivers. Riparian areas and floodplains in the lower reaches were frequently inundated by floods generated by intense Pacific storms. The jams caused localized flooding facilitating the spread of floodwaters over the floodplain and the deposition of fine sediments. The distribution of flood water across the floodplain helped to limit the magnitude of scouring forces acting upon stream channel beds and banks.

A vivid image of the complexity and dynamics of natural flood events is presented in an historic account of flooding and flood response in Tillamook County at the time of settlement in the 1850s (Collins, 1933):

Freshets of innumerable spring seasons had shoved and tumbled the fallen trunks [in the Wilson River valley]. Swirling red flood water had shouted and tugged at them and flung them into every elbow of the river channel; had piled new trunks upon them with each succeeding year and had plastered the whole conglomeration with red clay and dark loam torn from the higher levels of the hills.

Finally—and long before the first white settlers came—Nature had completed a series of formidable dams all along the stream. Under and around these obstacles the Wilson River found its way in the slack months of summer. Against them it raged and bunted in the high tide of winter. When the melting snows of the Coast Range poured down into the already swollen stream, the waters backed up into flood lakes that went eddying and swirling farther and farther across the level floor of the valley until they lapped the lower edges of the hills.

And each of these flood lakes, as they drained away, when the freshets ceased and the Wilson River returned to its channel, left toll of black loam upon the valley floor, deeper and richer each year until one can hardly compute their depth and the richness of the black fertility that had been storing up for ages before the settlers came.

This account provides a compelling view of the role flooding played in the evolution of the fertile floodplains in the Tillamook Bay area.

■ ***Tides***

Tidal action is responsible for the development of the sloughs and marshes that make up the estuary. Marsh environments are commonly described as either high or low marsh. The elevation difference between these two is very subtle, about 8 inches, but can have a substantial effect on the frequency of inundation, and salinity of tidal marshes. As a result, plant communities in high and low marshes vary considerably having evolved to withstand a variety of combinations of inundation and salinity. The highest elevation areas within the tidal zone of the Pacific Northwest coast support a unique tidal spruce forest community.

5.2 Human Alterations to the Landscape

Extensive conifer forests, occasional wildfires, floods, landslides, and the tides all contributed to the productivity of the vast Tillamook Bay estuary by contributing large wood and nutrients to the system and creating complex channel and slough forms. Flooding, fire, landslides, and sedimentation are all natural processes that occur in the Tillamook Bay Basin. However, these processes dramatically increased since settlement in the late 1800s, with effects to the ecological, social, and economic vitality of the region.

5.2.1 Changes in Upland Forests

Timber harvesting has been the primary human land use in the uplands. Logging activity historically increased fire frequency which, in turn, accelerated salvage logging with impacts to both aquatic habitat and down stream flood risk.

■ *Increased Fire Frequency*

Historically, the evergreen coniferous forests of the Pacific Northwest have a low-frequency high-intensity fire regime. In western Oregon the estimated fire interval for cedar, spruce, and hemlock forest was estimated to be 400 years.

After settlement in the mid 1800s, the frequency of fire ignition increased dramatically in the Pacific Northwest and enormous acreages were burned in the late 19th and early 20th centuries. In the Oregon Coast Range, very large areas of the Nestuca, Alsea, Smith, Nehalem, Tillamook and other rivers were consumed by human-caused fires between the mid 1800s and the early 1900s. In the large Coast Range fires of the 1800s, riparian forests were often left unburned and afforded an important source of seed for regeneration.

In 1902, the Tillamook watershed was described by a newspaper reporter as a continuous, unbroken old-growth conifer forest. In 1918 a runaway slash fire burned more than 100,000 acres in the Tillamook Basin. The great Tillamook fire of 1933 was one of the last of a series of catastrophic fires in the Coast Range.

A prolonged drought descended on the Oregon Coast Range in July and August of 1933. On August 14, 1933 logging operations ignited a small fire. The fire spread steadily in the tinder dry forest until August 24th, when a combination of extremely low relative humidity and strong winds caused the fire to erupt. It consumed 220,000 acres in 20 hours, exposing this massive area to severe winter storms. Two other fires were started in the Tillamook Basin in 1933, one by an arsonist. The fires burned along a 100-mile front for another two weeks until the first September rains came.

The major watersheds to the north and south of the Tillamook had been heavily burned in the six decades prior to the 1993 Tillamook fire. There were reburns of the Tillamook Basin during the summers of 1939, 1945, and 1951. The total acreage burned through 1951 was 360,882 acres, and much of this had been burned two or even three times, severely damaging the soil and inhibiting natural forest regeneration.

■ *Salvage Logging*

After the fires an enormous salvage logging and fire control effort began. A public/private conglomerate, called the Consolidated Timber Company, was created to conduct the salvage operations. The Rogers plan was adopted to guide the salvage and restoration effort which called for fire control, intensive salvage logging, the felling of millions of snags, the construction of a vast network of fire roads and the planting of extensive acreages of even-aged monocultures.

Although initiated with the best intentions, the Rogers plan lead to very serious environmental impacts and degradation. The felling of snags and salvage of burned wood lead to a regenerating forest that was lacking in large snags and large downed wood, which are among the most critical habitat components in Pacific Northwest forests. The honeycomb of logging roads severely fragmented the landscape and greatly increased surface erosion and mass wasting. The legacy of these impacts still affects habitat in the Tillamook Basin.

- ***Timber Harvesting***

Non-salvage timber extraction also has a profound effect on aquatic ecosystems. Logging and road construction near streams leads to increases in sediment load and water temperatures, and generally a decrease in fish production and/or diversity. The Coast Range is dominated by sedimentary and igneous rocks. Sedimentary rocks are more vulnerable to erosion. Both surface and mass erosion occurs on steep slopes, mostly after road construction and logging disturbance. Drainage systems and salmon habitats have developed in close association with oldgrowth conifer forest.

Logging of the valleys of the Tillamook Bay Basin began in the 19th century with ox teams and horses. With the advent of steam trains and donkey engines, logging expanded into the upland areas. In latter part of the 19th century, settlers moved into the woods from the estuary. There were more than 50 families settled on homesteads along the Wilson River. During WWI, spruce forests along the Oregon Coast were heavily logged to supply light and resilient wood for fighter planes. Commercial logging of the burn areas began again in 1983.

Past timber management practices have caused increases in sediment and temperature, decreases in available volumes and distribution of large wood, changes in water chemistry, increases in biological oxygen demand, and changes in hydrology. Activities of greatest impact have been logging in riparian zones and yarding activities in stream channels.

Poorly-managed logging in riparian areas leads to a disruption of the relationship between aquatic and terrestrial systems (Malanson 1993). Clearcutting and road building have been shown to be a significant cause of habitat fragmentation (Tinker *et al.*, 1998). Poorly managed logging has been shown to cause a reduction in juvenile anadromous salmonid diversity and abundance in several basins on the Oregon coast (Reeves *et al.*, 1993).

Cumulative effects of land cover changes are a significant source of ecological degradation in the Tillamook Basin. Much of the present day logging in the basin is done on steep slopes where cumulative effects are severe and frequent. Cumulative effects result from the collective impacts of one or more management activities and can exhibit threshold behavior, in which the impacts of management reach a critical point at which they cause major disturbances (Franklin, 1992). Cumulative impacts are likely to be a major cause of landslides, flooding damage, and salmonid population declines (Franklin, 1992).

A significant amount of the sedimentation that is affecting salmon spawning grounds in the Basin can be attributed to steep slope timber harvest which has been shown to cause dramatic increases in sedimentation infiltrating stream beds (Davies and Nelson, 1993). The sedimentation caused by logging has also been shown to have significant negative affects on stream amphibians (Corn and Bury, 1989).

- ***Landslides***

In the Coast Range, most landslides in recent years have occurred on managed lands between 1,000 and 2,000 feet in elevation, where slopes are steepest and precipitation heaviest. In the transient snow zone, landslides occur frequently as a result of rain-on-snow events in which large amounts of water infiltrate the soil on steep slopes (Berris and Harr, 1987). According to Pierson (1977), landslides with a mean volume of 270m^3, occur at a frequency of about one slide per km^2 every 17 years. This makes up approximately one quarter of the sediment that flows into streams from slopes in the Coast Range each year (Pierson, 1977).

Most debris torrents originate on steep slopes within headwater swales and on adjacent steeply-sloped and incised tributary stream channels. Many road fill failures result in large slides. Once these landslides enter steep stream channels they generate large-scale debris torrents. Approximately 65-percent of observed landslides end up as debris torrents, some of which can travel over two miles (Pierson, 1977).

The frequency of landsliding and debris torrent events is much higher in areas that have been recently clearcut and/or roaded. Land management actions play a clear role in the impacts of storms. Clear associations have been documented between roads and landsliding and recent clear-cutting and landsliding (Pierson, 1977).

▪ *Summary of Upland Changes*

Causes

- Construction of logging roads.
- Removal of live and downed trees from hill slopes, riparian areas, and channels.

Primary Effects

- increased water delivery to stream and transportation downstream
- increased sediment delivery to streams and transportation downstream to lowlands
- decreased nutrient input to streams
- decreased pool numbers
- decreased quality of spawning habitat
- decreased vegetative cover

Secondary Effects

- increased flood risk downstream
- decreased food, cover, and spawning habitat for salmon

5.2.2 Changes in Lowlands and Estuaries

Beginning in the late 1800s, the lowland rivers, floodplains, and estuary of the Tillamook Bay Basin were altered to ensure safe navigation of ships and to support the increasing use of the land for settlement and farming. These alterations frequently incorporated flood control measures. Similar strategies were employed to reduce flood risk and increase productivity in both the lowland and estuary environments so it is appropriate to discuss alterations to these areas together. Alterations can be grouped into three general categories: channelization, levee construction and floodplain dewatering.

▪ *River Channelization & Simplification*

Channelization simplifies the form of a channel. Channelization strategies include **dredging** and **large wood removal**, and the construction of **cut-off dams**. Dredging increased channel depth and flow capacity while wood removal improved navigation access to upstream areas and increased river flow capacity. Cut-off dams were constructed to block the mouths of secondary channels or to shorten the course of the river by eliminating bends (Figure 5-1). When a bend is eliminated the river drops the same elevation in a shorter distance. The result of this is fewer channels carrying the same amount of water in steeper, larger channels. The simplification of what was once a complex system of side channels reduced the amount of channel area that the river had access to at high flows and eliminated off-channel areas that sheltered salmon during those same high flow events. This simplification also increased flow velocities and the erosive forces acting on the banks of the main channels.

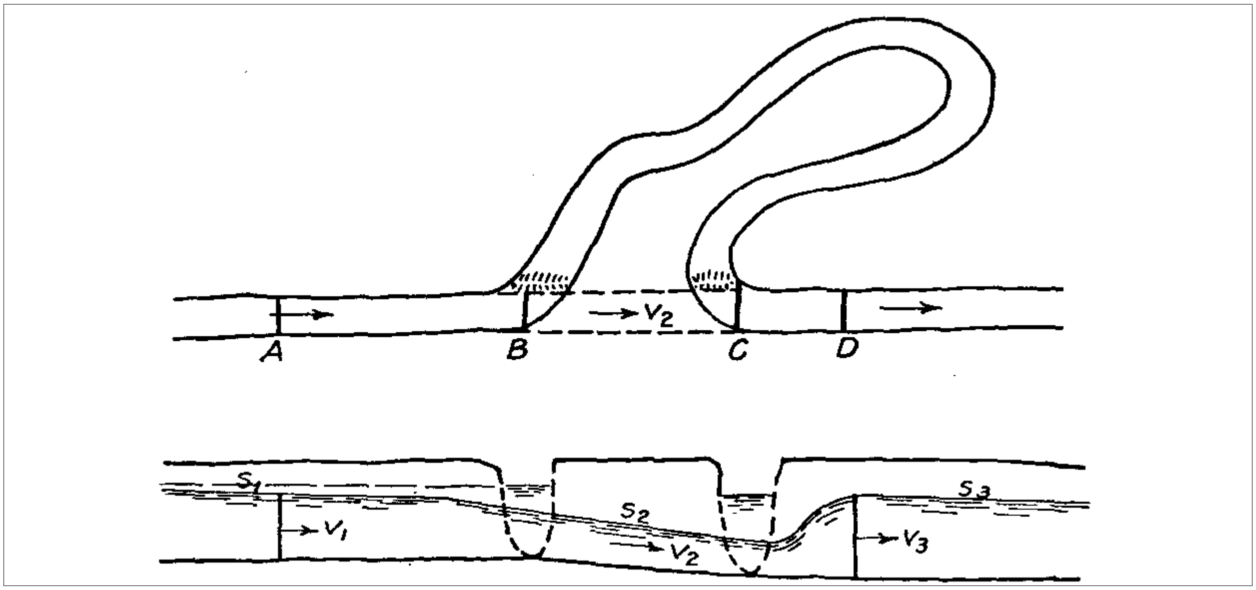

Figure 5-1. Effect of a River Channel Cut-off on River Flow Source: Etcheverry, 1931

■ *Levee and Dike Construction*

In a natural river system, as floodwaters overflow the river banks, coarser sediments are initially deposited along the banks often forming natural levees several feet higher than the surrounding floodplain. The elevated river banks naturally divided the lowland valley into overflow basins bounded by the valley hillslopes (Etcheverry, 1931). Finer sediments are typically carried further onto the floodplain where they are deposited in areas of slack water during floods.

In the early 1900s, the traditional practice for reclaiming floodplain lands for agricultural purposes was to place a levee, or dike, along or near the riverbank to take advantage of the higher ground provided by the natural ridge of high ground formed from sediment deposits from past overbank flooding (Figure 5-2). Besides protecting the greatest amount of floodplain land from flood overflows, this practice resulted in the construction of levees requiring less height and less cost than would otherwise be necessary if they were constructed at lower ground elevations farther from the river.

The design of a levee and its foundation was dependent on the anticipated duration and height of floodwaters against the levee (Etcheverry, 1931) (Figure 5-3). Levees bordering bays and not exposed to wave action were recommended to be built to an elevation 3 to 5 feet above the highest tide (Etcheverry, 1931). The use of willows as protection for levees was recognized in a 1931 engineering textbook. It was recommended to plant rows of willows in front of levees because they "grow rapidly and their branches break up the waves and decrease the currents [against levees] (Etcheverry, 1931). It is interesting that these same techniques are now being advocated for salmon habitat restoration.

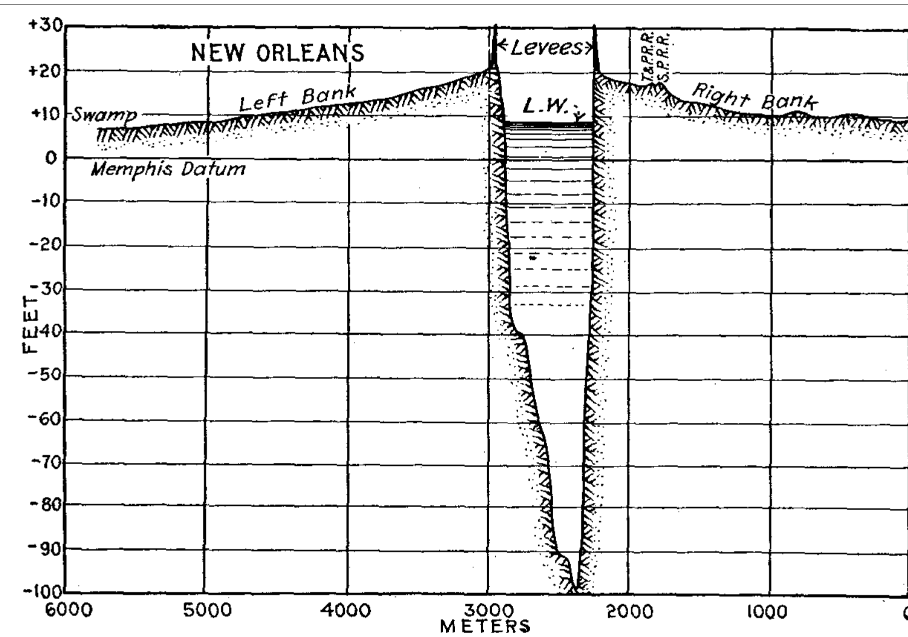

Figure 5-2. One example of Levee Construction on top of the Natural Levees of a River
Source: Van Ornum, 1914

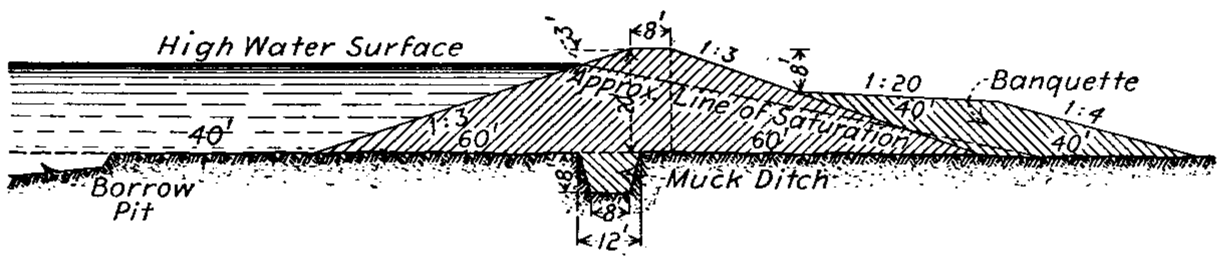

Figure 5-3. A Typical Levee Section Source: Van Ornum, 1914

The protection of lands in lowland valley floodplains typically occurred gradually over time, as various landowners or drainage districts would isolate their particular areas without regard for the future conditions caused by these cumulative impacts in the floodplain. Levees alongside one side of a river were constructed to heights to contain the highest floodwater experienced, but as subsequent drainge projects occurred in upstream areas and on opposite banks of a river flood waters would increase and lead to competition of levee heights (Etcheverry, 1931).

Although the concept of cumulative effects was probably not considered as levees and dikes were being constructed in the early part of this century, it is interesting to note that the engineering textbooks published at this time for guidance in land drainage and flood protection addressed these effects. Etcheverry (1931) did caution against constricting both sides of a river with levees because the loss of natural overflow areas would increase flood levels against the levees. He also acknowledged the removal of natural floodplain overflow areas by levees would increase the "intensity of flood discharge." The practice of levee construction was generally promoted in the early textbooks as an effective method to protect lands from flooding, if only one side of a river was to be leveed (Etcheverry, 1931). With both sides leveed, it was recognized that the loss of the floodplain overflow areas would eliminate the floodplain's absorbing effect on the flood peak and result in higher water levels against the levees. Setting both levees back from the riverbank was proposed as an economical solution to this problem (Etcheverry, 1931).

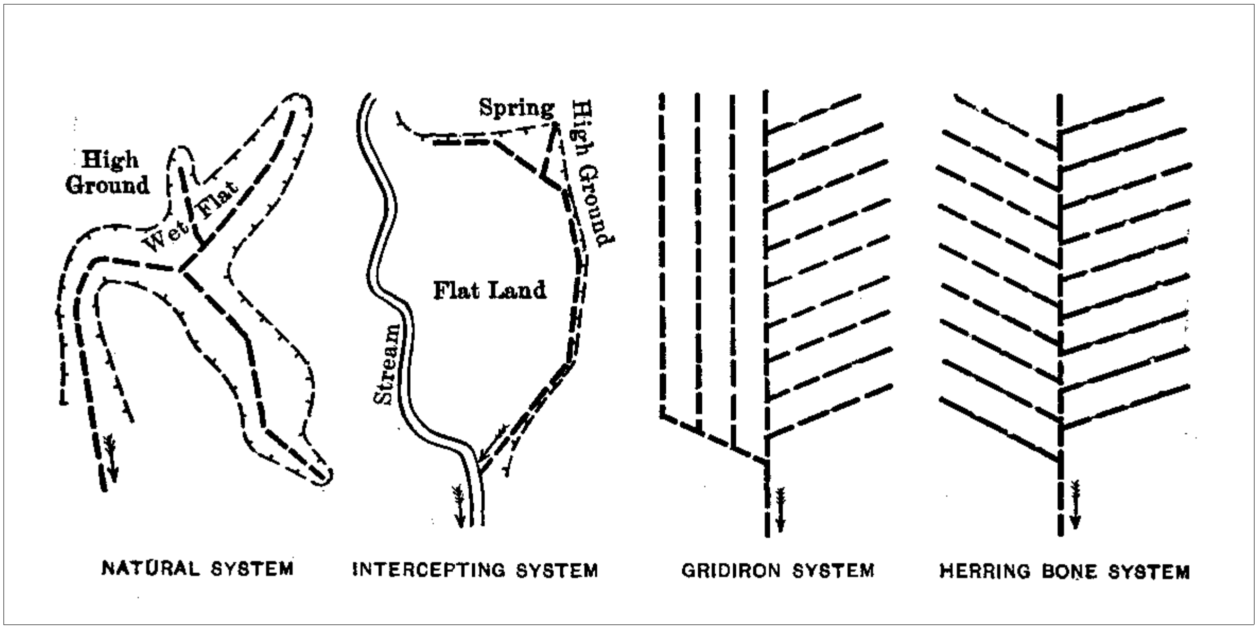

Figure 5-4. Types of Tile Drainage Systems Source: Powers and Teeter, 1932

▪ *Floodplain Drainage*

Complete reclamation of diked and leveed floodplain lands often required the additional use of surface and subsurface drainage facilities to remove excess water from direct precipitation, high seasonal groundwater levels, or flood overtopping of dikes and levees. Land drainage was achieved through the use of ditches, tidegates and buried drain tile.

Drainage techniques were employed to increase the productivity of land in agricultural use. Drainage tiles, placed below the surface of agricultural land removed excess water and increased the length of the growing or grazing season. It is understood that drain tiles were installed across much of the Tillamook Bay lowland valley floodplains to provide seasonal subsurface drainage of lands protected by dikes and levees (Figure 5-4). However, information on the exact location and extent of these drainage features is not readily available.

The dewatering of floodplain soils for agriculture has proved effective for converting these natural lands over to productive lands for grazing and field crops. However, the long term effects of these activities typically results in significant physical changes to the land. The predominant change is land subsidence, or a lowering of the land surface. Land subsidence within drained floopdlains can be caused by oxidation of the soil, when naturally moist soils are drained and exposed to the air, resulting in changes in soil chemistry and a compaction of the soil structure. Subsidence can also occur from the direct compaction of soil due to the weight of grazing animals and vehicles.

Floodplain drainage efforts typically interrupt the supply of sediments and inorganic materials from the rivers and the bay to floodplain lands. This reduces the ability of tidal marsh lands to receive natural sedimentation and increase in elevation to keep pace with a rising sea level.

These physical changes to the elevation of the land surface can lead to dramatic changes in the movement of water on the land. Lower land areas, if restored to river flow and tidal action, may experience more frequent inundation and changes in fresh and salt water flow and mixing. Hydrologic changes can, in turn, lead to changed vegetatio patterns and aquatic habitats.

■ *Summary*

The history of river channelization and levee and dike construction in the Tillamook Bay lowlands was typical of this era of land reclamation and drainage, in that it proceeded in a manner that solved immediate drainage problems for individual landowners without consideration for the cumulative and longterm effects of the flood protection structures. In order to maximize the amount of land to be protected from flooding and minimize the costs of levee and dike construction, these flood control features were often built immediately alongside of rivers to take advantage of the higher ground where natural levees had formed. The cumulative effects of these drainage alterations were not considered as their use spread across the lowland valleys.

Interestingly, many of the actions considered today to improve the integrity and effectiveness of these types of flood control structures, while improving the environmental conditions of floodplains and riparian areas for fish and wildlife habitats, were promoted at the beginning of this century. The same engineering textbooks that provided guidance for the construction of levees and dikes advocated setting back levees from rivers to reduce the potential for erosion and overtopping of the structures. The use of natural vegetation, such as willows, in front of dikes and levees was also recommended to absorb the energy of waves and river currents and reduce the chances of erosion and minimize maintenance needs.

■ Summary of Lowland Changes

Lowland changes and their causes, and primary and secondary effects, are summarized below.

Causes

- Construction of roads
- Removal of live and downed trees from riparian areas, and channels
- Removal of wetland vegetation
- Cutting-off side channels from main channels
- Reinforcement of channel banks
- Construction of dikes and levees
- Construction of drainage projects
- Grazing in riparian area
- Gravel mining

Primary Effects

- increased volume and velocity of water in main channels
- decreased water quality
- decreased flooding and sediment deposition on the floodplain
- increase in the amount of sediment passed downstream to estuary
- decreased nutrient filtering in wetlands
- decreased pool number and frequency
- decreased spawning gravel
- decreased vegetative cover
- decreased refugia

Secondary Effects

- increased flood risk downstream
- increased bank erosion
- decreased food, cover, rearing, and spawning habitat for salmon

■ **Summary of Estuary Changes**

Causes

- Removal of live and downed trees from riparian areas, and channels
- Removal of marsh vegetation
- Cutting-off sloughs from main channels
- Reenforcement of channel banks
- Construction of dikes and levees
- Construction of drainage projects
- Dredging
- Grazing

Primary Effects

- increased volume and velocity of water in main channels
- increase in the amount of sediment passed downstream into the bay
- decreased water quality
- decreased tidal action in marshes
- decreased nutrient filtering in marshes
- decreased scour hole numbers
- decreased quality of spawning habitat
- decreased vegetative cover
- decreased refugia
- oxidation and compaction of soil
- soil surface subsidence
- increased duration of surface inundation by freshwater in highly subsided diked marshes

Secondary Effects

- increased flood risk downstream
- increased bank erosion
- decreased food, cover, and rearing habitat for salmon
- shellfish closures
- decreased palatability of vegetation where subsidence leads to development of freshwater wetlands

5.3 Historic Salmon Abundance

The historic salmon productivity of the Tillamook Basin is directly related to the historic landscape conditions and alterations to these conditions just described. Understanding the connection between historic salmon populations and these changing landscape conditions allows us to determine how human alterations to the landscape may have detrimentally affected salmon productivity.

5.3.1 Estuary Size

Although small when compared to estuaries globally, Tillamook Bay is a significant size and large in proportion to its drainage basin when compared to other estuaries along the Oregon Coast (Figure 5-5). This is of significance because estuaries and tidal wetlands are the most productive natural systems. Tiner (1984) has demonstrated that saltmarshes are the most productive ecosystem in terms of biomass generated per unit area, greater than even tropical rainforests.

However, it is not just biological productivity that is impacted by the loss of wetland acreages but also biological diversity. A general 'rule-of-thumb' for ecosystems is that 80% loss of habitat will result in a 50% reduction in the number of species. Since many of the coastal regions of the U.S. have already exceeded this critical number, the need to preserve or enhance remaining wetlands is of paramount importance. Further, the type of sub-habitat is important to many species which use wetlands and it is important to maintain the diversity of open water, mud-flats, channels, pannes and eco-tones. The timing and volume of freshwater inflows affect patterns of mixing within estuaries, and because of linkages between salmon production in freshwater and estuarine habitats these are critical habitats for protection and restoration.

Drainage basins with proportionally larger estuaries may be inherently more productive for salmon than basins with smaller estuaries, at least for those species with extended periods of estuarine residency. One of the reasons for this is that large estuaries may be less prone to perturbations in water quality or anthropogenic influences, and able to recover faster. For example, a wildfire in a small system may influence the entire system, resulting in overload of fine sediments, loss of streamside vegetation, altered geomorphic characteristics that makes the entire system untenable for certain species - pushing the species to extinction. A larger system is less likely to be 100% impacted, allowing isolated pockets of habitat and fish to survive, allowing the population to build out again as the physical system recovers.

5.3.2 Historic Abundance

Salmon evolved with the patterns of disturbance and recovery described above and use the upland, lowland, and estuary environments at different stages of their life cycles. Information on turn of the century abundance of salmon in the Tillamook Bay basin and other coastal Oregon drainages is imperfect but important in helping to gain insights on the inherent productivity of their aquatic systems. This information, usually in the form of cannery records and old fishery statistics, can often be used to establish reasonable (although by no means precise) estimates of the sizes of historic salmon runs and thus to establish points of reference that may provide useful guidance to restoration planners.

Lichatowich and Nicholas (1991) and Huntington and Frissell (1997) have developed these types of estimates for many of Oregon's coastal river basins. For most basins, these estimates reflect salmon abundance after Euro-Americans had caused a considerable amount of environmental change in lowland areas and estuaries.

The Tilamook Bay basin’s historic capacity to produce immense numbers of salmon reflect the areas diverse environment. The significant historic abundance of chum salmon in Tillamook Bay, documented in cannery records, is evidence that much of the river system's historic productivity was linked to the presence of high-quality habitat in the extensive lowlands surrounding Tillamook Bay and the bay itself because chum salmon spawn in low-gradient streams and spend up to a month as juveniles rearing in estuaries.

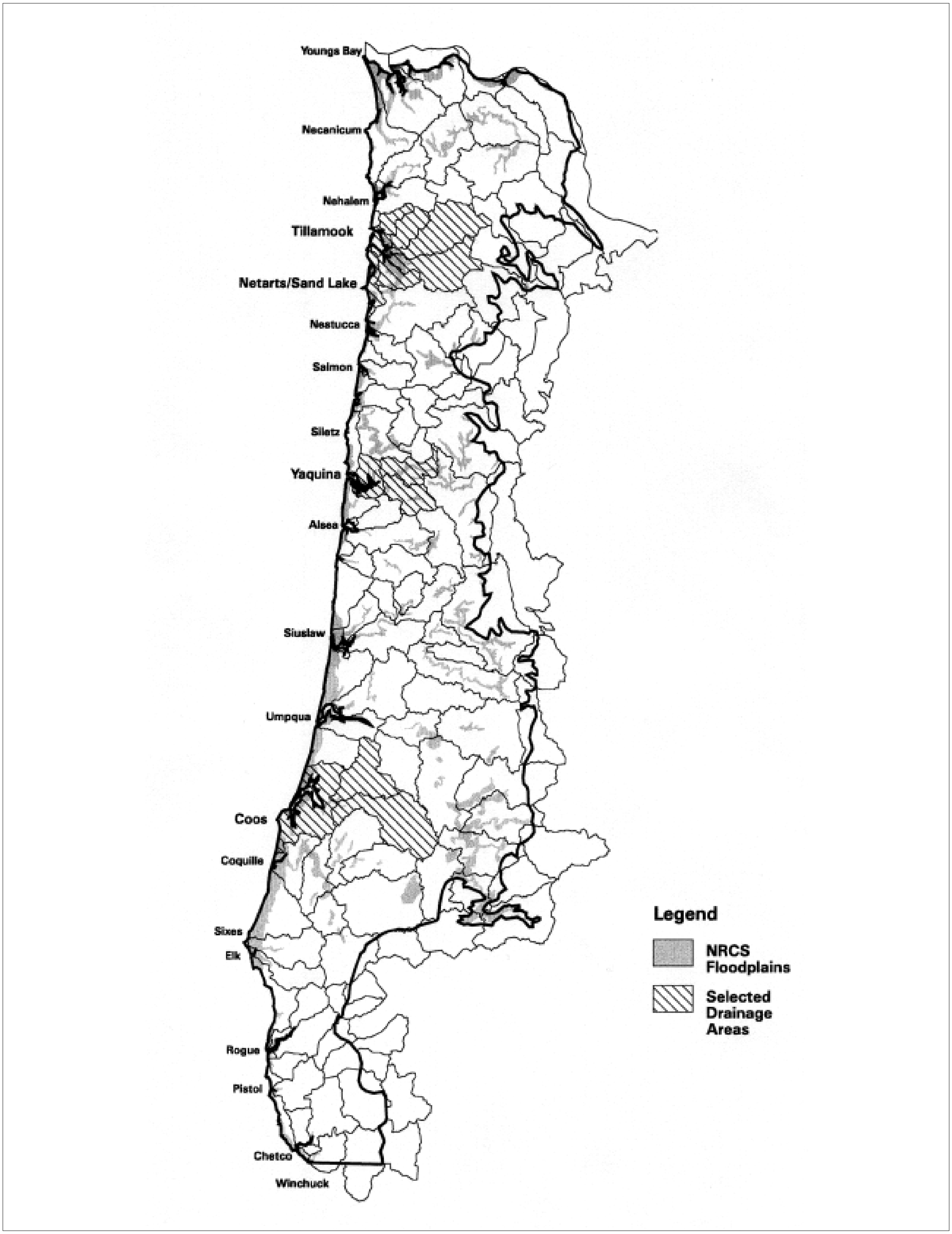

Figure 5-5. Oregon Coast Ecoregion with River Basins

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6. Tillamook Bay River System Characterization

This section of the report provides a series of assessments that define the current state of the river systems in the Tillamook Bay Basin. The assessments provide a compilation of basic data that will be used to develop an IRMS for the Tillamook Bay Basin. Conclusions from the assessments are presented in GIS maps, tables, charts, or diagrams. The goal was to make the conclusions as meaningful and understandable as possible within the constraints of available data and funding. Conclusions derived from GIS were mapped at either the basin extent (Figure 6-1) or the lowland valley floodplain extent (Figure 6-2). The lowland valley floodplain extent is a subset of the geomorphic lowland valley floodplain. Assessment mapping was focused on this smaller area because much of the available spatial data covered this area. The smaller area also allowed the development of a more detailed vegetation analysis (Appendix A).

The assessments are grouped in eight categories: Regional Precipitation and Climate, Basin Landform, River Hydrology, River Hydraulics, Tidal Processes, Vegetation, River System Morphology, Salmon Habitat and Distribution, and Human Land Use and Flood Risk. Each group of assessments builds upon those that precede it and illustrates the integrated relationship between natural and cultural systems. The natural system assessments begin by describing in spatial and temporal terms the interaction between land and water in the basin, moving on to vegetation and salmon distribution. The interaction between land and water is the foundation of the form and function of river systems. River and floodplain forms, combined with flood and tidal processes, create the conditions required to support a variety of native plant communities. These plant communities affect the way tides and floods alter landscape forms and are therefore essential to the geomorphic process. The complete system composed of water, land form, and vegetation in turn supports terrestrial and aquatic species such as salmon. The same conditions that support native plants and salmon have also encouraged human inhabitation in the Tillamook Bay Basin.

The assessments done for this report are intended to support the OWEB Oregon Watershed Assessment Manual, so many of the assessments correspond to activities described in the most recent version of this manual. However, the assessments done here are limited to those that help determine where and how flood risk reduction and salmon habitat enhancement can be achived in a coastal watershed. There are also a number of assessments of coastal and tidal processes that were added because they are not addressed in the OWEB manual. These processes are an integral part of the lowland river systems in the Tillamook Bay Basin and were considered important for assessing estuarine habitat in light of recent Endangered

Species Act listings. They can be done relatively easily and may provide valuable information for Oregon watershed councils. With the exception of institutional characteristics, these assessments also support the categories for the analysis of river corridor conditions presented in Chapter 7 of the Federal Interagency Stream Restoration Working Group manual (Federal Interagency Stream Restoration Working Group, 1998).

These assessments were used to develop an understanding of natural processes and land use patterns with the Tillamook Bay Basin. This understanding was the basis of an IRMS. To demonstrate the IRMS, a concept plan for the lowland valley in the vicinity of the City of Tillamook was developed to locate, at a planning level, potential management actions within the lowland valley. GIS was used as an assessment tool because of its ability to describe the spatial coincidence between natural flood and tidal processes, post-flood permit activity, and salmon habitat. This spatial information was used to locate potential lowland valley actions. All of the assessments, including those using GIS, relied upon available data.

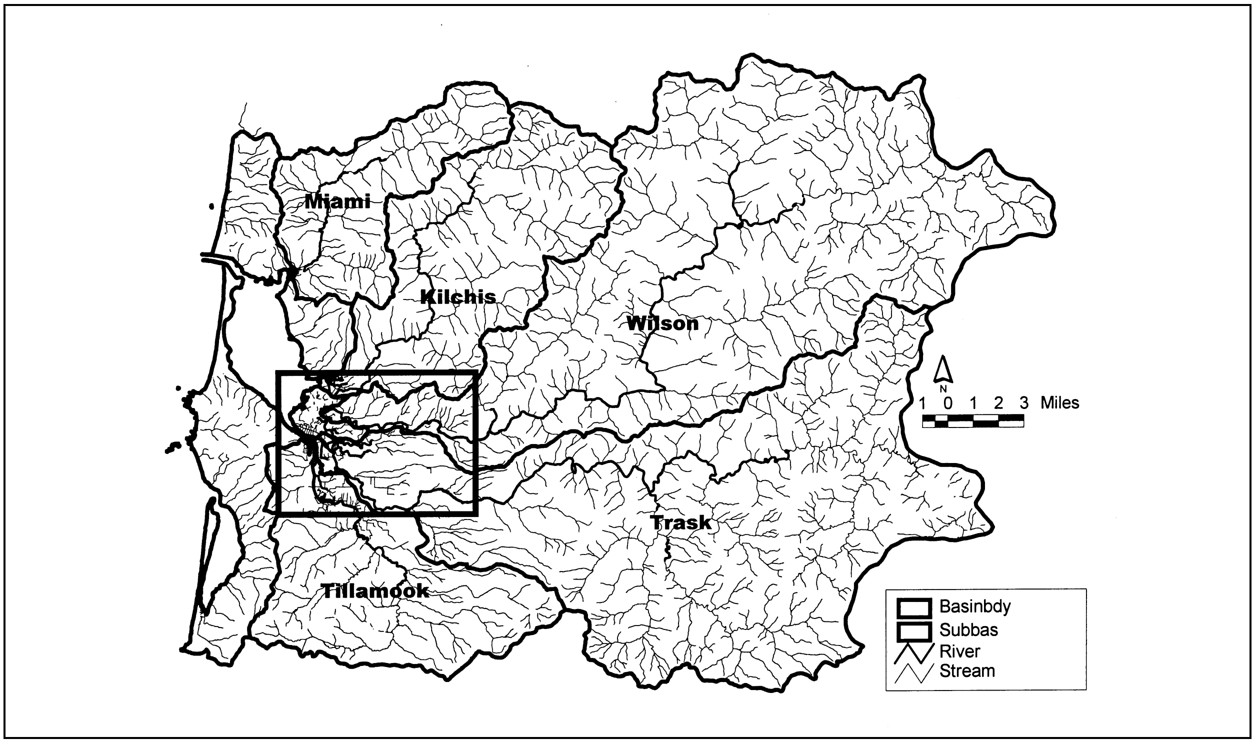

Figure 6-1. Basin Scale Map Extent

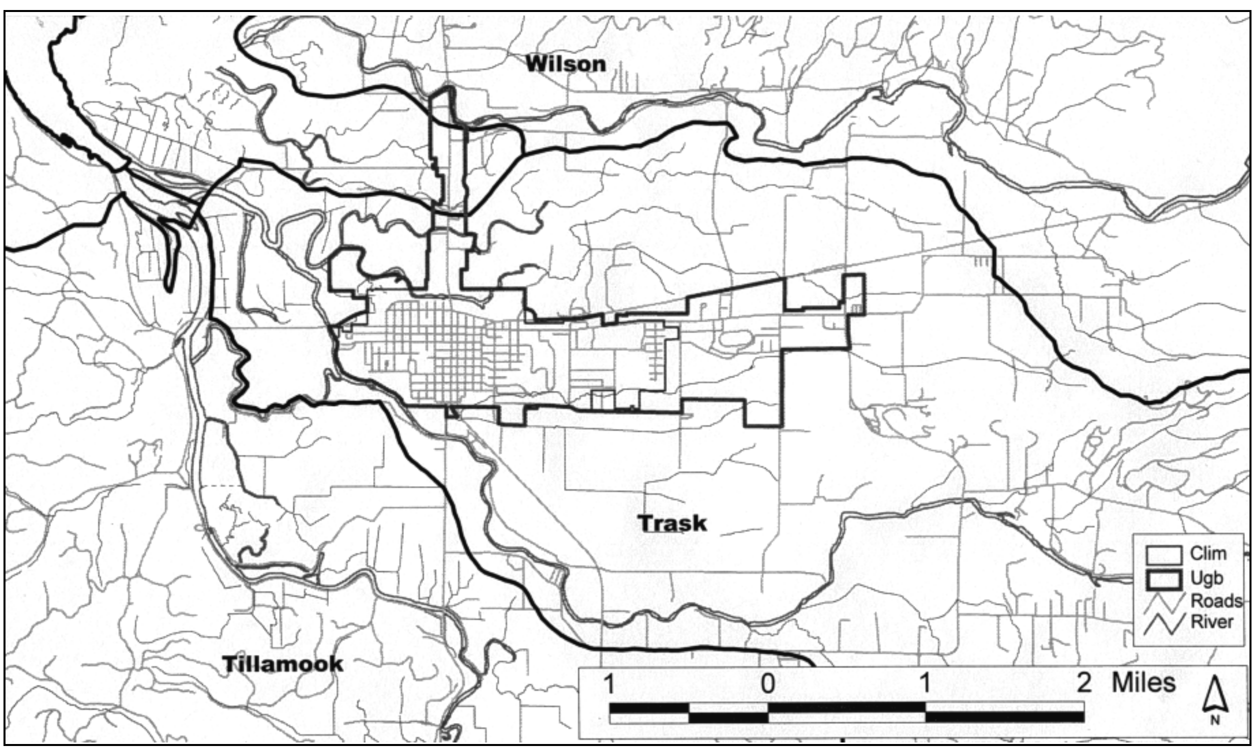

Figure 6-2. Lowland Scale Map Extent

6.1 Regional Precipitation and Climate

Precipitation and climate control the amount, timing, and distribution of water in a river system. They are the principal components affecting both flood risk and salmon population viability. This section discusses precipitation history and trends in the Tillamook Bay watershed, as well as winds, and sun angles.

6.1.1 Precipitation History and Trends

■ Objectives

Precipitation, an important part of the hydrologic cycle, is the result of climatic and topographic factors, and is the predominant source of water into a fluvial system. The objective of the precipitation history assessment was to characterize past regional and local precipitation trends in the Tillamook area, and to predict future trends and their effect on fisheries and floods.

■ Methods

Historic regional precipitation trends for the Oregon Coast were obtained from the Oregon Climate Service (OCS) web site (http://www.ocs.orst.edu). Precipitation at all stations west of the crest of the Coast Range was averaged for each water year. Figure 6-1-1 provides a summary of each year's departure from average water year precipitation from 1896 to 1995. The bars indicate individual water year departures and the line graph indicates a 5-year moving average. Figure 6-1-2 provides a historic summary of water year precipitation for the Oregon Coast area from data also obtained from the OCS.

■ Discussion

Four climatic periods are identified in Figure 6-1-1, alternating between wet and cool periods and dry and warm periods. These periods are generally 20 years in length. Because the last dry and warm period began in 1976, there is a possibility the Oregon Coast may currently be headed into a period of cooler and wetter weather.

These climatic cycles have a direct bearing on flood potential, and have recently been recognized as a possible indicator of salmon behavior, with cooler and wetter conditions being more favorable for the survival and resurgence of salmon. Wetter weather conditions also have direct implications for increased flooding potential, depending on the ability of the watershed system to absorb precipitation and attenuate runoff. Therefore, it may become increasingly important to manage the forested upland watershed areas of the Tillamook basin to slow the movement of water when it enters the river system as precipitation.

The fluctuation between annual and 5-year-average water year precipitation (Figure 6-1-2) appears to be increasing in recent years, as compared to the moderate changes that occurred up to 1945. This variability may have implications on moisture stress and plant growth rates for vegetation basin-wide, including upland forests, lowland agricultural areas, and revegetation efforts associated with floodplain restoration.

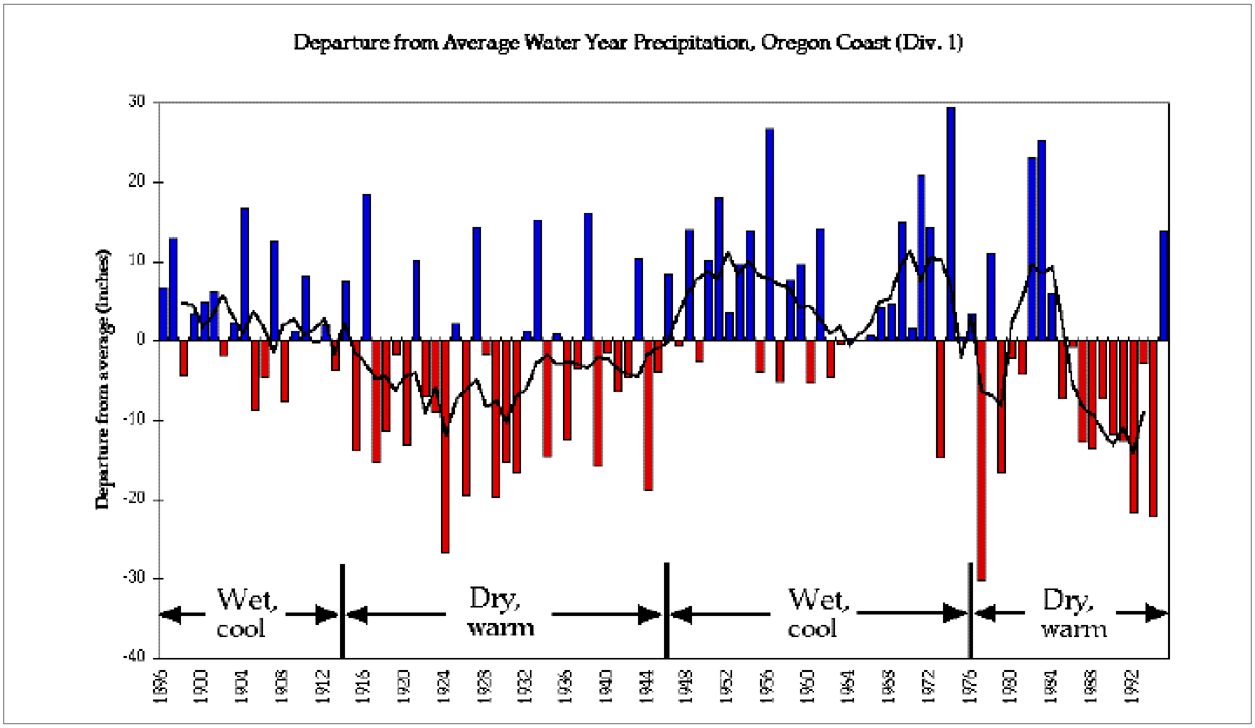

Figure 6-1-1. Departure from Average Water Year Precipitation, Oregon Coast (Div. 1)

6.1.2 Wind Direction and Sun Angle

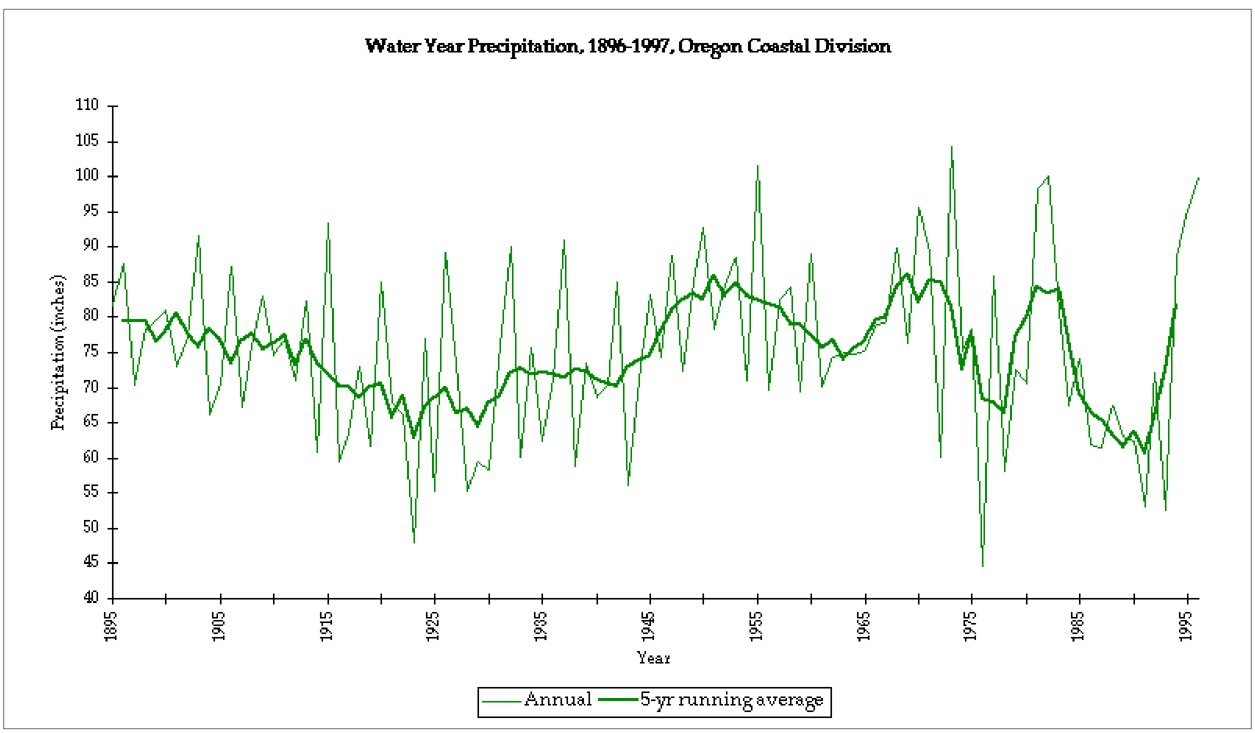

Figure 6-1-2. Water Year Precipitation, Oregon Coast 1896-1997 (with 5-year Smoothing)

Objectives

The objective of this assessment was to understand the characteristics of seasonal wind directions and sun positions, in order to guide the conceptual layout of shelterbelts as a land management measure with multiple benefits for agriculture, flood management and fish and wildlife habitat interests.

Methods

Monthly and annual wind data for Tillamook (wind speed class, direction and frequency) were obtained from the Climatological Handbook for the Columbia Basin States. These data were published in 1968, but are the most recent available for the Tillamook area, and likely remain representative of seasonal wind characteristics.

Figure 6-1-3 shows an annual summary of wind percentage frequency by direction for Tillamook. Predominant wind directions are from the South and the Northwest. Figure 6-1-4 shows representative summer and winter wind percentage frequency by direction using the months of July and January, respectively. Southerly winds generally occur during the late fall and winter, and northwesterly winds occur during the summer months through the growing season.

The annual variation of the angle of the sun was assessed by documenting the altitude of the sun, the angle in degrees from the horizontal (Figure 6-1-5). The sun altitude was estimated at weekly intervals throughout a representative year (Figure 6-1-6) using software available over the Internet [www.susdesign.com/sunposition].

Discussion

Given this generalization of the wind directions for Tillamook, several shelterbelt concepts can be formulated. Shelterbelts may be most beneficial for fish when planted along the northwest edges of streams, such that leaves, twigs and other organic matter are blown into the water and contribute to the food source for benthic invertebrates and, in turn, for fish. Meanwhile, shelterbelts placed along the southern edges of streams can shade surface waters to moderate water temperatures and improve water quality for fish and other aquatic organisms. The sun's position throughout the year (Figure 6-1-6) can be used to guide the placement and height of riparian plantings in relation to water bodies, so that the beneficial effects of shading are optimized during key fishery life cycle stages.

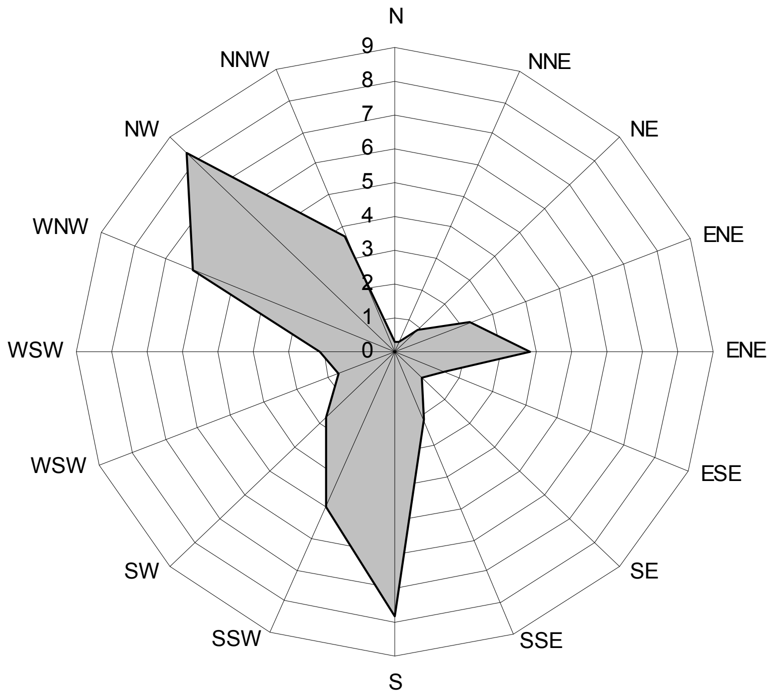

Figure 6-1-3. Annual Percentage Frequency of Wind by Direction for Tillamook County

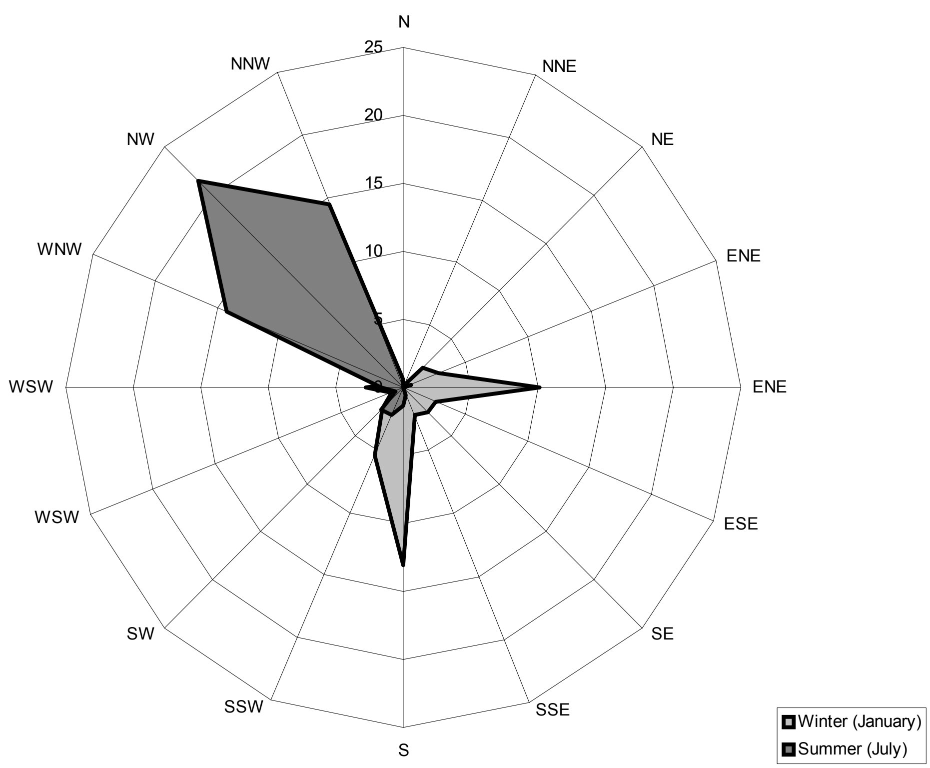

Figure 6-1-4. Representative Percentage Frequency of Summer and Winter Winds by Direction for Tillamook County

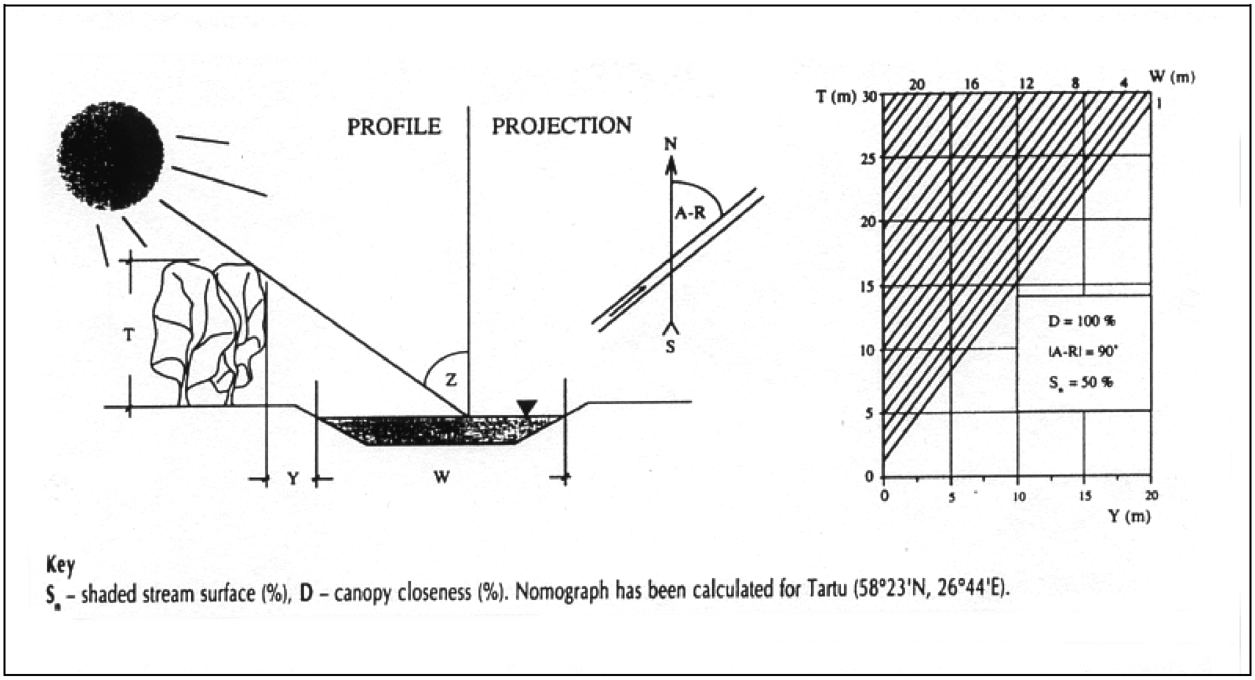

Figure 6-1-5. Scheme and Nomograph for Estimation of the Optimal Parameters of Streamside Vegetation to Stream Surface Shade Source: Eiseltova and Briggs, 1995

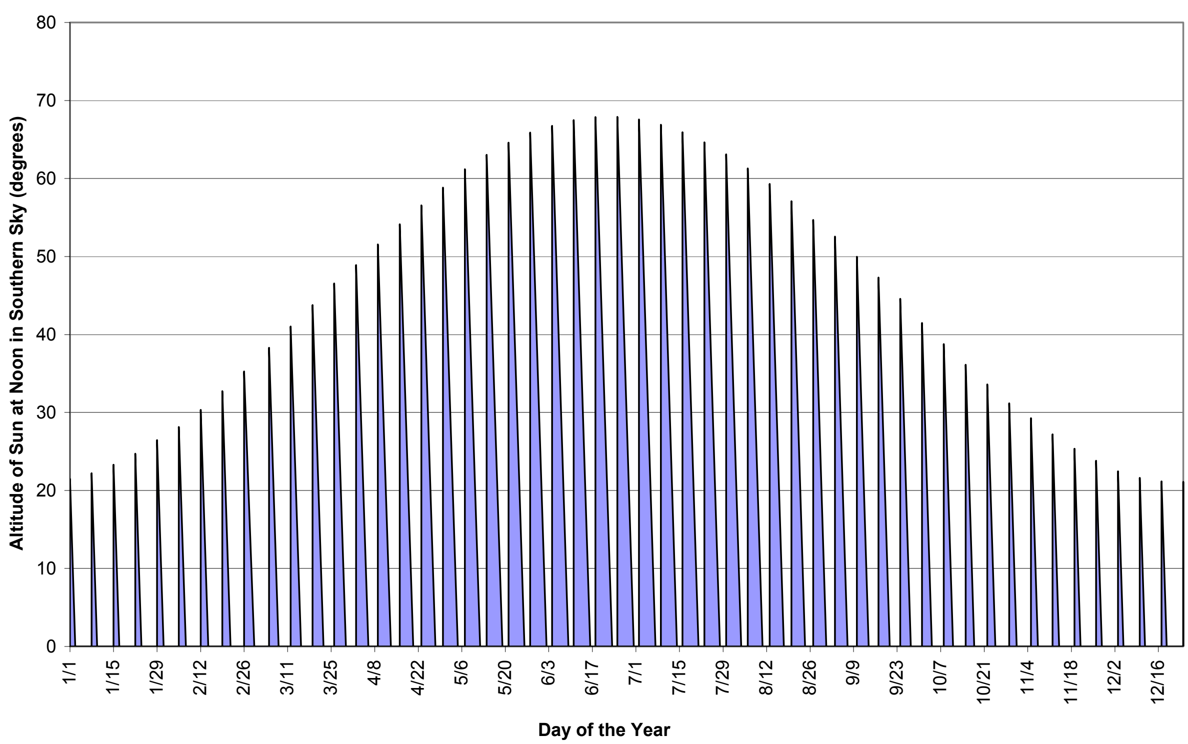

Figure 6-1-6. Annual Variation of Sun Position in Tillamook County [Latitude 45.5 degrees north]

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6.2 Basin Landform

Landform includes elements that describe the topography and geology that make up a landscape. Landform composition affects weathering and vegetation growth, which in turn determine the rate at which runoff enters a river system and the amount and type of sediment that the system is likely to transport. This section covers watershed delineation, topography, geology, stream channel gradients, and longitudinal profile.

6.2.1 Watershed Delineation and Topography

■ Objectives

The objective of this assessment was to delineate the primary watersheds within the Tillamook Bay Basin and to show the relationship of those watersheds to the topography and geology of the basin's five major rivers, the Miami, Kilchis, Wilson, Trask, and Tillamook.

The topography of the Tillamook basin is described to help characterize its effect on hydrology and to provide a general template for understanding the spatial extent of flooding. In addition, topography can be used to evaluate the potential for processes such as soil erosion and slope failures.

■ Methods

The watershed boundaries shown (Figure 6-2-1) were generated digitally from digital elevation models (DEM), but they can also be created manually by tracing high-quality topographic maps.

USGS 7.5-minute topographic maps and historical aerial photographs were used to describe the broad-scale topography of the five watersheds in the Tillamook basin. In addition, 10-meter resolution DEM coverages were used to produce GIS maps describing the elevation (Figure 6-2-2), slope, and aspect (Figure 6-2-3) of the watershed at the basin scale.

■ Discussion

The Tillamook Bay covers up to 12 square miles at high tide. Five major rivers flow into the bay. Four of these, the Tillamook, Wilson, Trask, and Kilchis, flow from the Southeast and are part of the major floodplain of the basin. A fifth river, the Miami, flows into the bay from the Northeast. The bay receives water from 550 square miles of steep forested hillsides and flat lowlands.

The Tillamook basin is characterized by steep, forested slopes along the eastern, northern, and southern extents of the watershed. Elevations reach a maximum of 3,690 feet. In the upper basin, river channels are generally moderately confined by adjacent hillslopes. Below an elevation of 100 feet, the basin grades into the valley floor. Here, unconfined channels traverse the valley, ultimately reaching Tillamook Bay.

Precipitation on the steep relief of the uppermost portions of the watershed is likely routed rapidly downhill. As streams converge and gradient decreases rapidly, large volumes of water accumulate in the lowermost alluvial valleys, resulting in valley flooding.

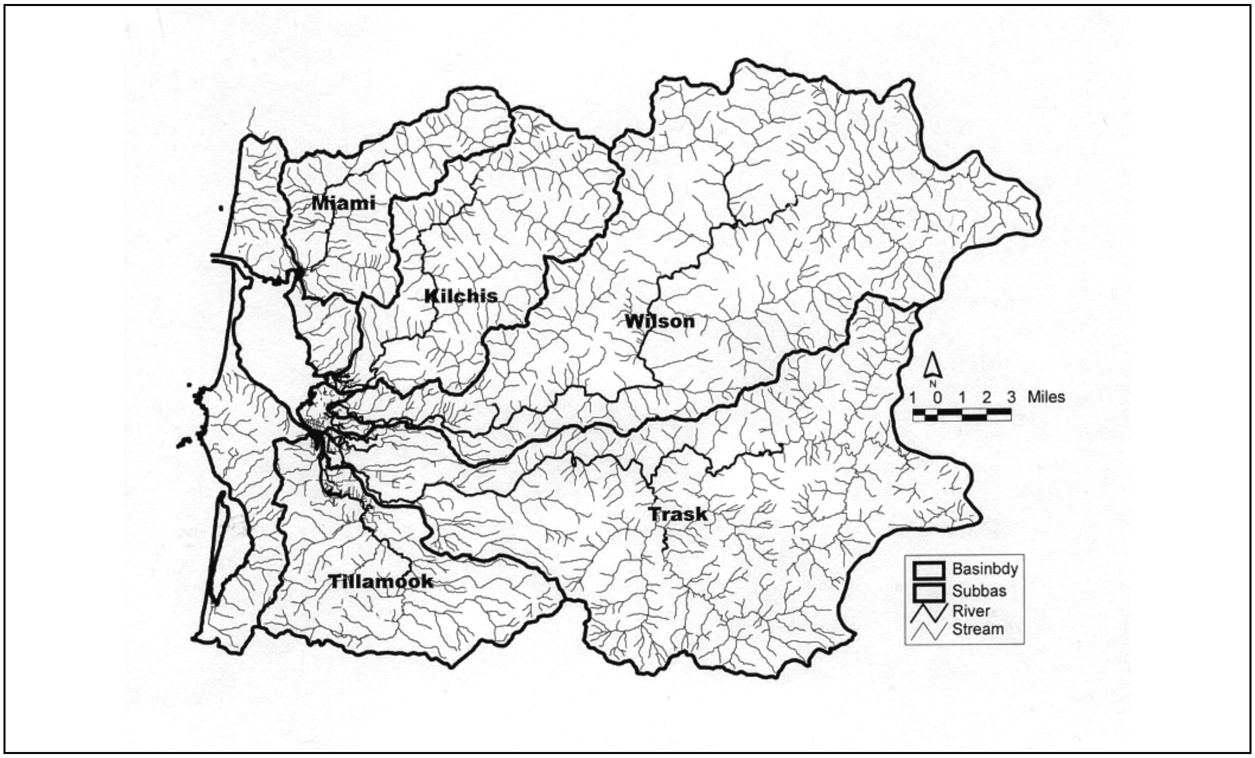

Figure 6-2-1. Tillamook Bay Basin Watersheds

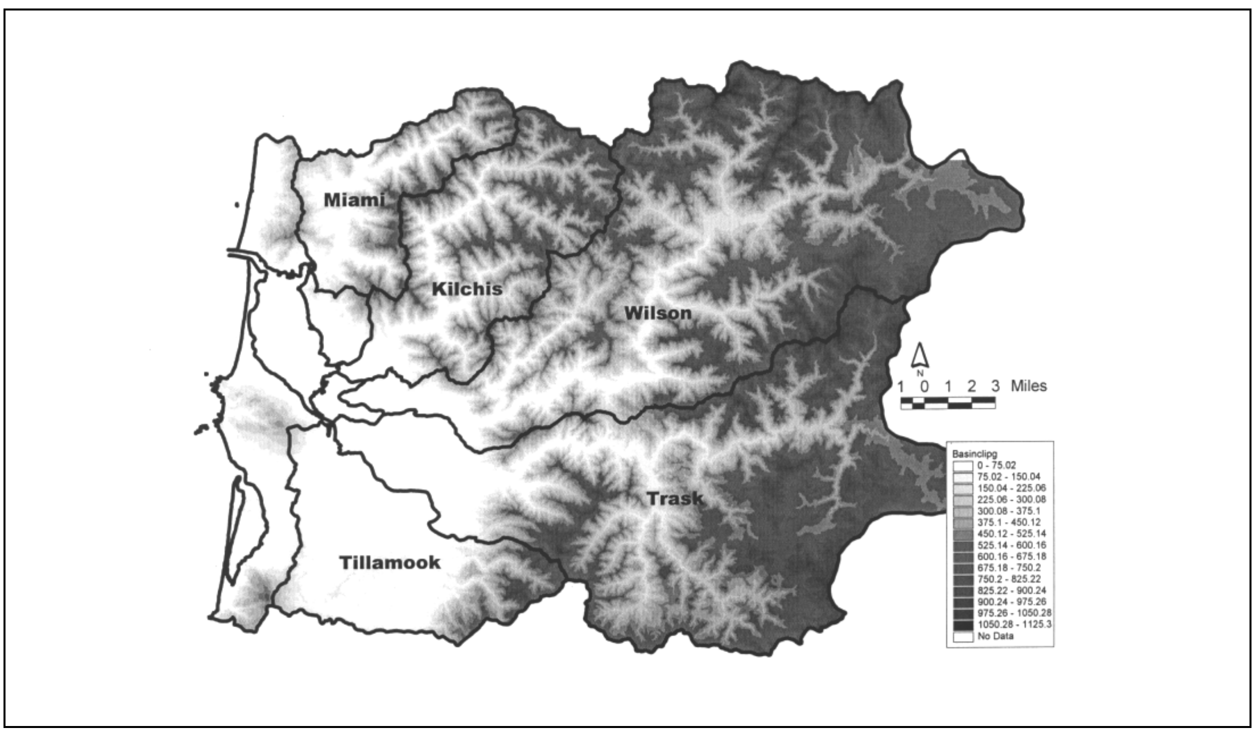

Figure 6-2-2. Tillamook Bay Basin Elevation in Meters

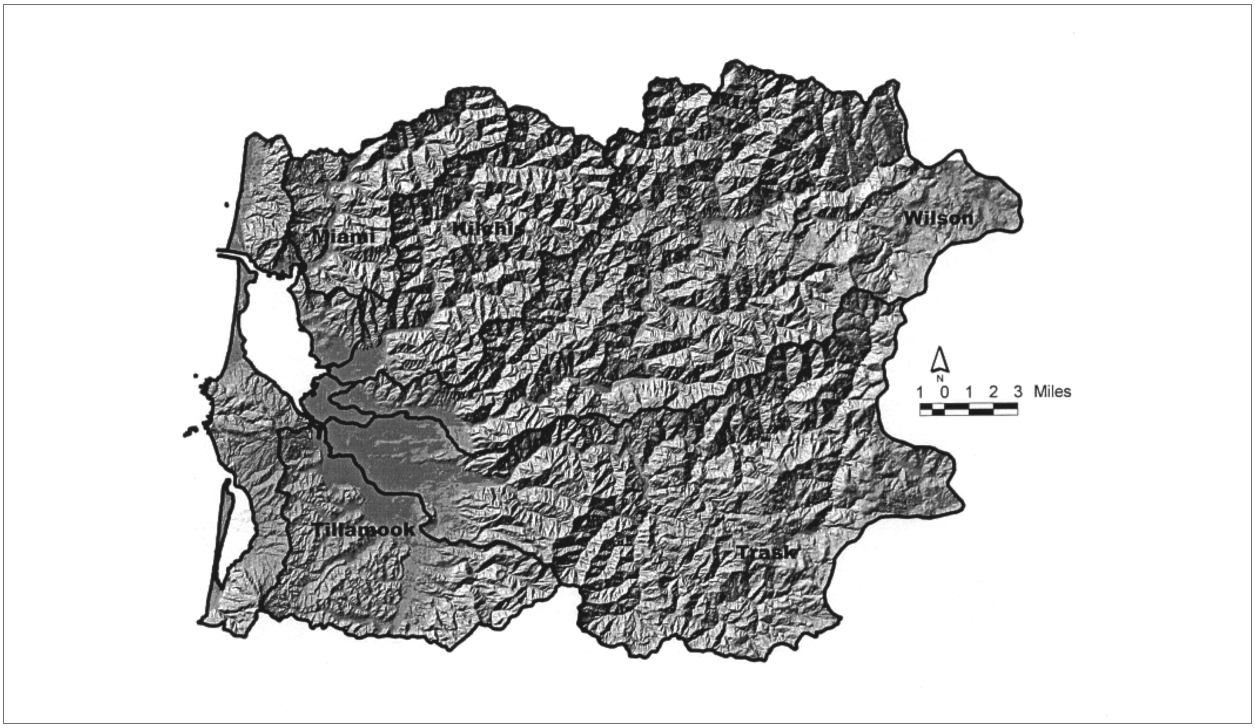

Figure 6-2-3. Tillamook Bay Basin Hillshade (a Graphic Representation of Aspect)

6.2.2 Estuary Size

▪ Objectives

In its historic natural state, the 582-square mile Tillamook Bay basin provided a highly diverse physical habitat for plants, animals, and aquatic species such as salmon. The diversity of these habitats was largely a reflection of the geomorphic characteristics and interrelationships of the basin's uplands, lowlands, and estuary. To gain a better understanding of its historically diverse and productive aquatic ecosystems we compared the size of the Tillamook Bay estuary to its surrounding drainage basin and to the estuaries elsewhere in coastal Oregon.

▪ Methods

The assessment of estuary size was based on summaries of Oregon's coastal estuaries by Percy *et al.* (1974), along with planimetric measurements of additional estuary and watershed areas taken from 7.5-minute USGS topographic maps.

▪ Discussion

Although small when compared to estuaries globally, Tillamook Bay is large in proportion to its drainage basin when compared to other estuaries along the Oregon Coast (Figure 6-2-4). This is of significance because estuaries and tidal wetlands are the most productive natural systems. Tiner (1984) has demonstrated that salt marshes are the most productive ecosystem type in terms of biomass generated per unit area, greater than even tropical rainforests.

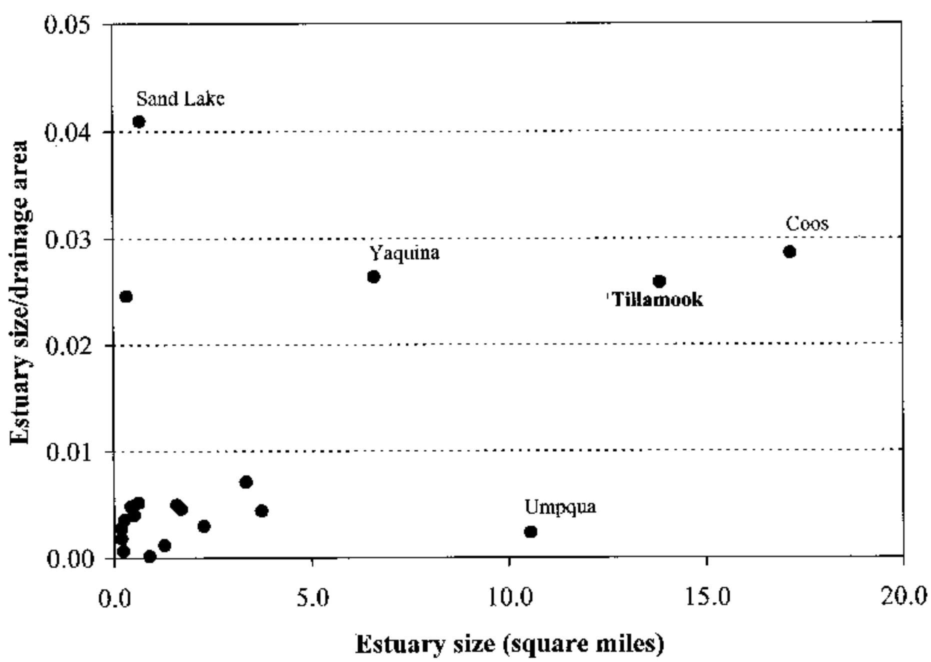

Figure 6-2-4. Estuary Size and Drainage Area for Oregon Coastal Basins

6.2.3 River System Classification

■ Objectives

Watershed morphology is controlled by slope, water discharge and sediment supply (Montgomery and Buffington, 1993). The landscape within a watershed can be generally divided into three spatial scales: watershed, valley and channel reach (Figure 6-2-5). The spatial arrangement of source, transport and response reaches within these watershed divisions can be an indication of the degree of potential impacts and recovery times from disturbances to the river system. The objective of this assessment was to perform a reconnaissance-level classification of the basin watershed and river system, including source, transport and response landforms and river areas, in order to develop a conceptual model of watershed processes.

■ Methods

Reconnaissance-level channel classification methods developed by Montgomery and Buffington (1993) (Figures 6-2-6) were used together with the 10-meter DEM of the basin to define the spatial extent of source, transport and response areas within the basin and along the river channel network based on land slope. The entire land surface of the basin was categorized according to the slope classes of 30% and greater for source areas, 30% to 3% for transport areas, and less than 3% for response areas (Figures 6-2-7 to 6-2-9). This mapping extends beyond the linear river channel network to include hillslopes and terrain features, and provides a general indication of the spatial variation of watershed processes within and beyond the river channel network.

■ Discussion

A majority of the basin land surfaces exceed 30 % slope and serve as source areas for sediment. The Kilchis subbasin appears to have the greatest density of source areas (black shading in figure 6-2-7), with high concentrations also located along ridge lines and generally throughout the lower third of the forested uplands that ring the lowland valley of the south bay. Attention should be focused on these areas for source control management efforts, to limit disturbances that may increase runoff and erosion. This is especially true where source reaches are directly tributary to lowland valley response reaches, where increased sediment loads from disturbances could not be stored and gradually released to the lowland valley rivers, as could be done in connecting transport reaches.

Transport reaches (dark shading in figure 6-2-8) may be higher priority areas for the installation of engineered wood jams to increase sediment trapping. Transitions between transport and response reaches can be significantly impacted by increased sediment supply (Montgomery and Buffington, 1993), and these locations along river channels should be monitored to assess channel morphology responses. Since anadromous salmon tend to spawn in pool-riffle reaches of the river system where slope is between 0.1 and 2 percent (Figure 6-2-6), these response reaches (Figure 6-2-9 shaded areas) should receive prioritized attention for management and protection.

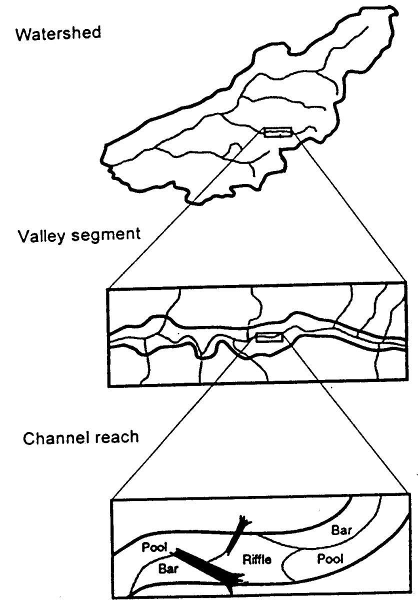

Figure 6-2-5. Landscape Classifications Illustrating Process Divisions at the Watershed, Valley Sediment and Channel Reach Levels (After Montgomery and Buffington, 1998)

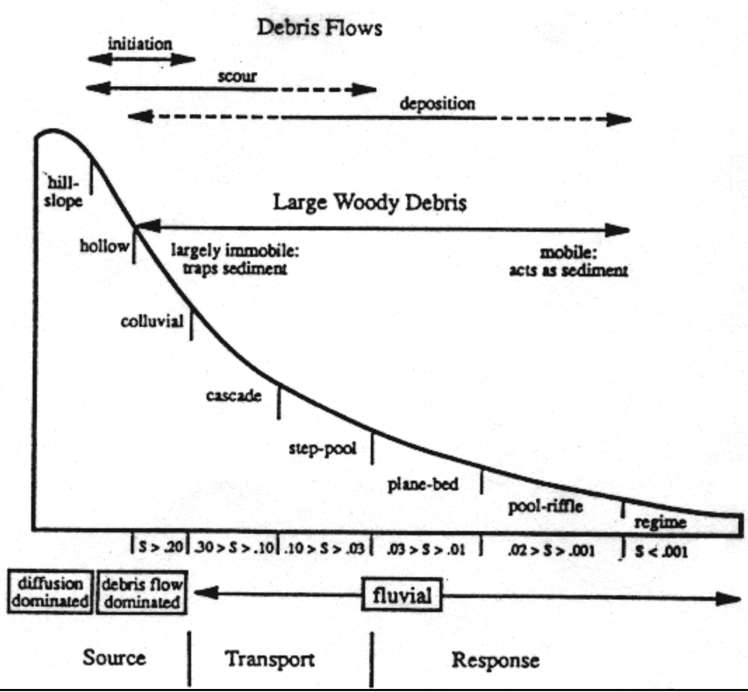

Figure 6-2-6. Debris Flow Source: Montgomery and Buffington, 1997

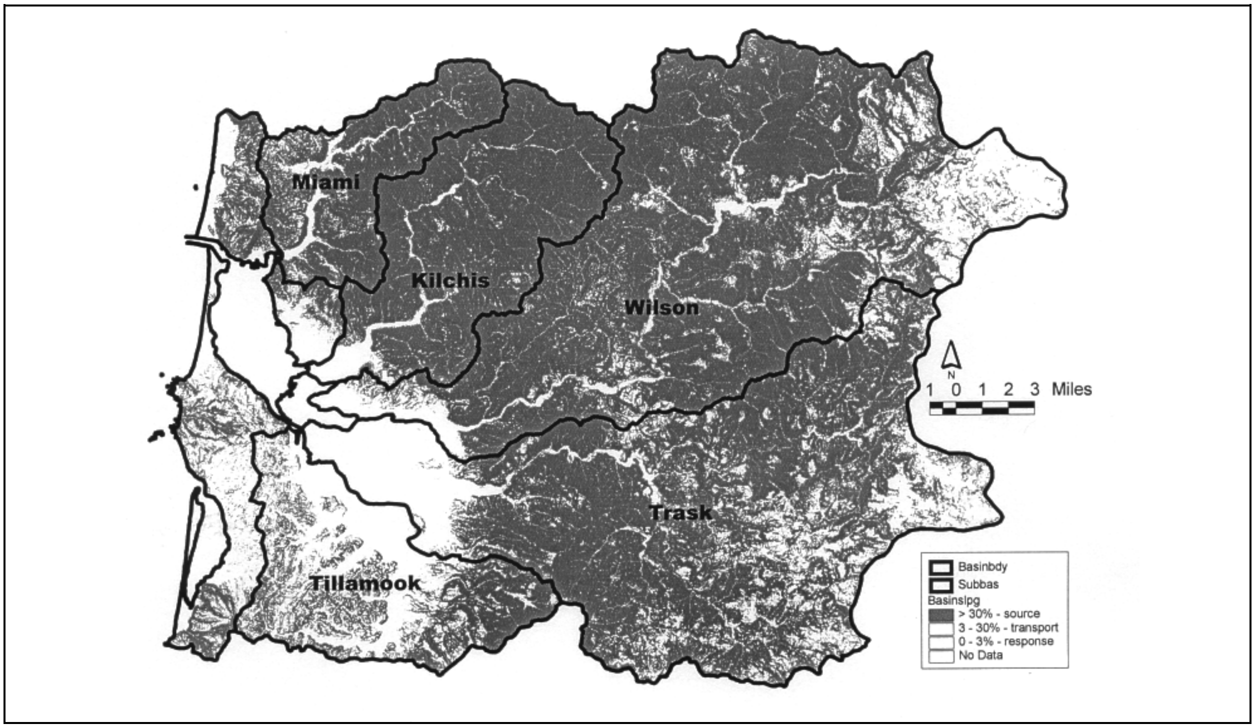

Figure 6-2-7. Basin Slope > 30% - Source Zone

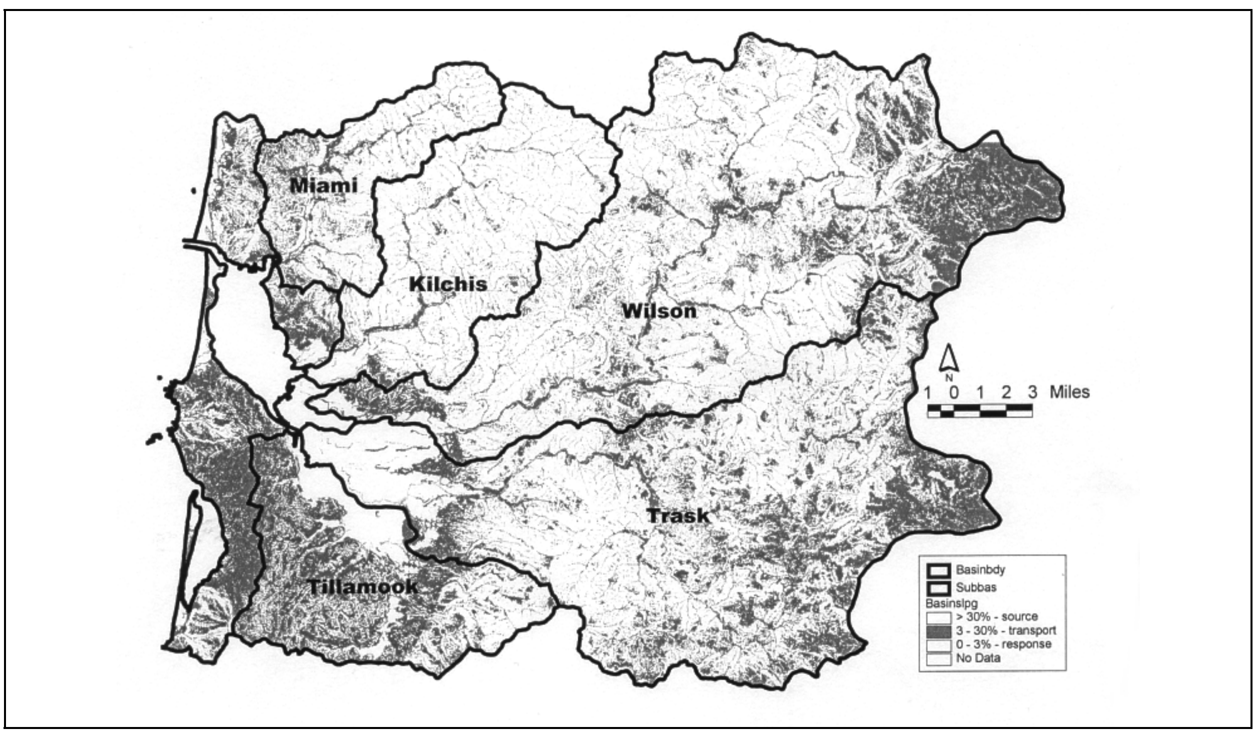

Figure 6-2-8. Basin Slope 3 to 30% - Transport Zone

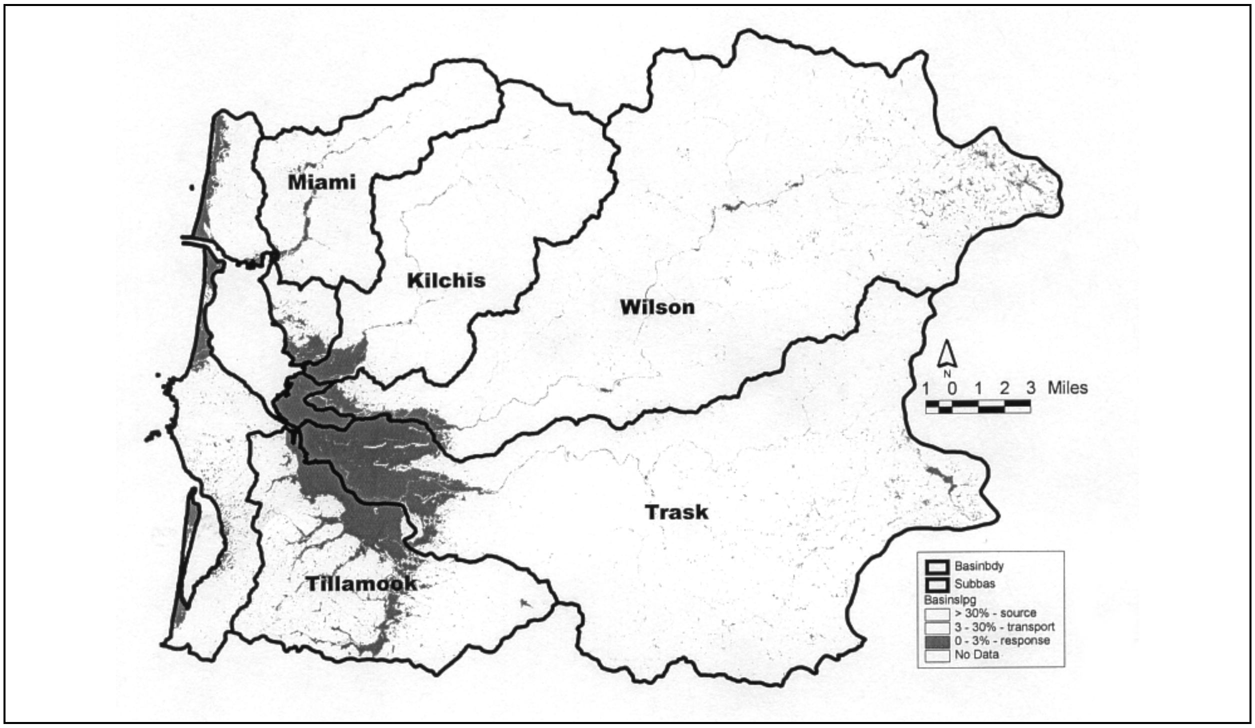

Figure 6-2-9. . Basin Slope < 3% - Response Zone

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6.3 River Hydrology

River hydrology describes the timing, amount, and duration of water moving through a river system. These values can be measured at specific landscape locations through the use of stream gauges. Gauge data provide a historical record and a body of statistical value observations, which can be very useful in understanding seasonal patterns of stream flow and flooding, and in turn, their effects on salmon habitat and flood risk. This section covers streamflow gauging and streamflows in the Tillamook Basin, flow duration, flood frequency, and flood wave and flood pulse concepts.

6.3.1 Mean Daily Streamflows

- **Objectives**

The objective of this assessment was to develop an understanding of the daily variability and magnitude of streamflow to guide flood management and floodplain restoration planning.

- **Methods**

Mean maximum and minimum daily discharge values for the Wilson River were obtained directly from the USGS because these data are not available over the Internet.

- **Discussion**

These seasonal flow data can be translated into river stage elevations in upland and lowland reaches of the river system, once the relationship between stage and discharge is known from field observations and/or floodplain computer modeling. The resulting stage discharge relationships can be used together with floodplain topography to estimate the depth, lateral extent and duration of flooding at various locations along the river system.

Maximum mean daily discharges exceed the flood stage of the Wilson River (13,200 cfs) during the months of December through February (Figure 6-3-1). Knowledge of the river stage elevations associated with these high discharges can be used in the restoration design of seasonal wetlands and floodplains.

Viewing the data on a semi-log plot (Figure 6-3-2) helps to show the variability in the minimum mean daily discharges through the water year. The lowest values of mean daily discharge (August through September) tend to be indicative of baseflow conditions, when a majority of the river flow is derived from groundwater sources.

The average mean daily discharge, and the discharges between the maximum and minimum mean daily discharge values represent the range of daily discharges that can be expected throughout the water year. Since these flows are daily values, and not longer-term monthly average values or short duration peak values, they represent the daily flow conditions occurring during plant growing seasons. The translation of these flows to river stage elevations can be used to guide restoration re-vegetation efforts by defining the elevation and extent of aquatic and riparian plant communities for given floodplain topography. For example, aquatic vegetation would be expected to grow at elevations below the stage of minimum mean daily discharges because land below this elevation would remain consistently wet; similarly riparian vegetation would be expected to grow above the minimum mean daily discharge stage and up to the mean or maximum mean daily discharge stage because these land areas would be periodically wet.

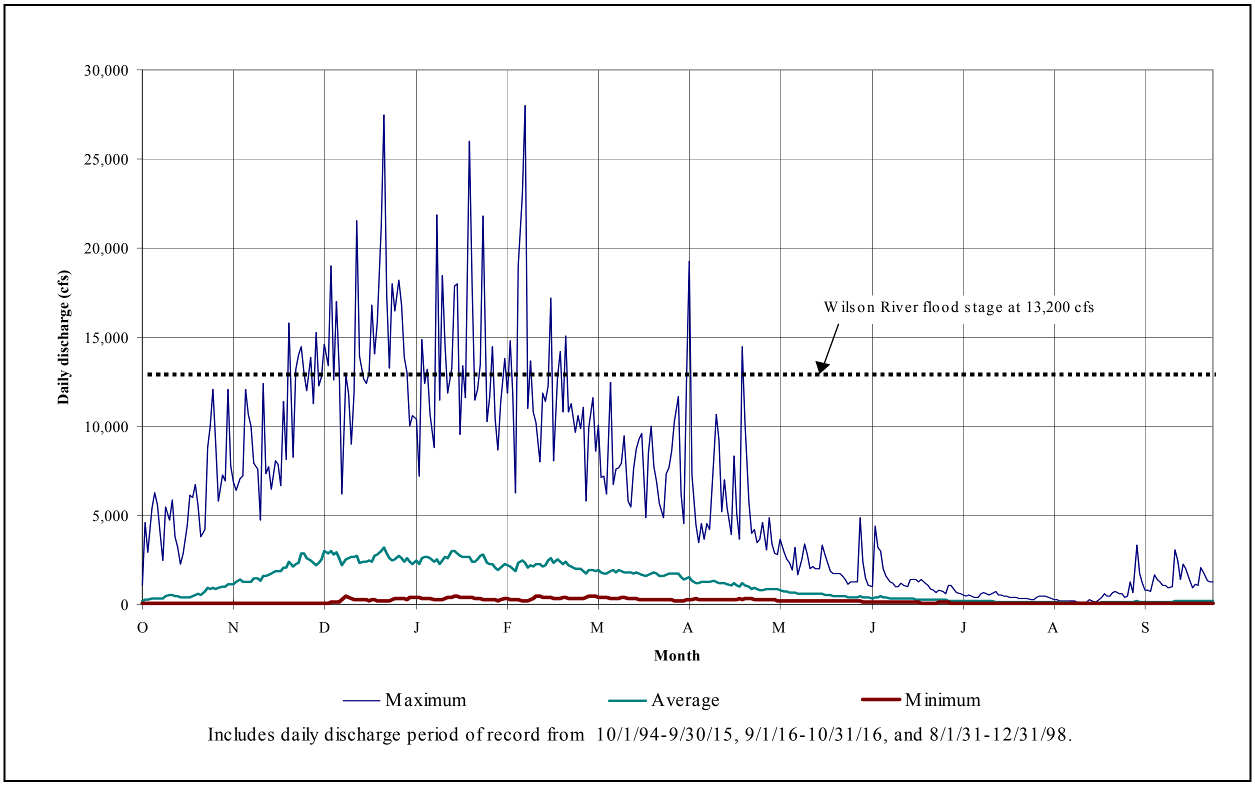

Figure 6-3-1. Wilson River Mean Daily Discharge (Maximum Mean Daily Discharge Focus)

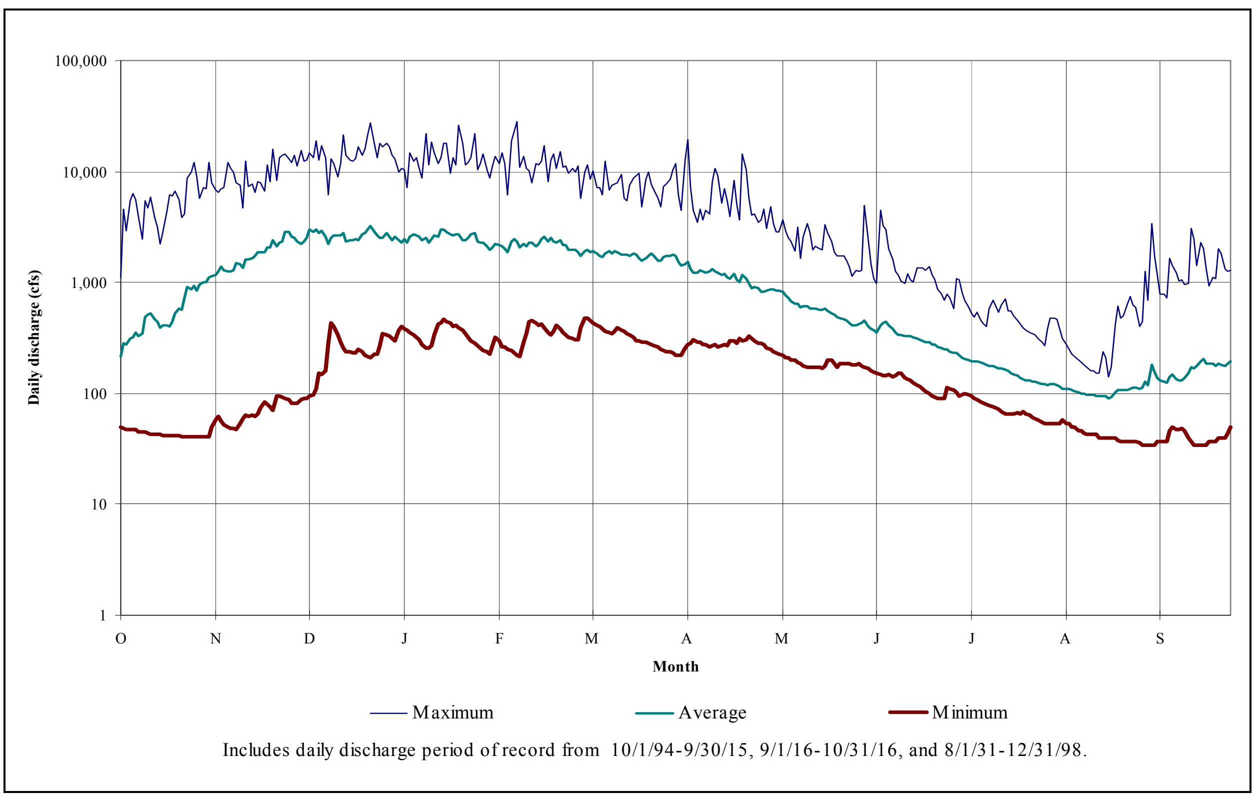

Figure 6-3-2. Wilson River Mean Daily Discharge (Minimum Mean Daily Discharge Focus)

6.3.2 Flood Event Hydrographs

■ **Objectives**

The objectives of this analysis were to compare: 1) the rate of rise and fall of historic flood event hydrographs; and, 2) the duration and volume of flood events, to assess the effects of historic flood hydrograph characteristics on streambank erosion.

■ **Methods**

Flow values for bankfull and flood stages were estimated by comparing river stage data from the National Weather Service (NWS) to the recent rating table (stage-discharge relationship) for the Wilson River stream gauge obtained from the USGS. For example, the NWS has designated a 13-foot river stage as "flood stage." This corresponds to a discharge of about 13,200 cfs from the USGS rating table. The area of the flood event hydrograph above flood stage represents the volume of water exceeding flood stage (Figure 6-3-5).

Floods travel downstream in a river system as a wave (Figure 6-3-3). The flood's wave is recorded at a streamgauge and the resulting record of the wave is the flood event hydrograph. Flood event hydrographs provide a chronology of the variation of streamflow over time. Hydrographs show the peak flow of a given flood event, but they also document hydrologic conditions before and after the peak of the event. Additional hydrologic conditions of interest (Figure 6-3-4) are the volume of the flood event (indicated by the area under the hydrograph curve) and the speed at which the flood peaks and recedes (indicated by the slope of the rising and falling limbs of the hydrograph). In the Tillamook Bay basin, the rate of the rise and fall of flood stage is of particular interest because "flashy" floods can saturate and destabilize the soil of levees and dikes, leading to erosion.

Hourly discharge data for the Wilson River gauge were obtained from the USGS for the period from October 1994 through April 1998 (the period of record for which hourly data is readily available). Peak discharges for the five largest flood events were identified, and the range of flood discharge values were selected from the data by including all values greater than an assumed base flow determined from visual inspection. Flood peaks were aligned together at a common time (day number 200) so that hydrograph limbs could be readily compared. Ordinates for the December 1964 flood event were taken from a figure of the flood hydrograph in the Corps post-flood report (Corps., 1972). Figure 6-3-6 shows a comparison of flood hydrographs for the Wilson River for flood events for the December 1964 flood and those flood events between October 1994 and April 1996.

■ **Discussion**

All flood events appear to have had similar durations above the 13,200 cfs flood stage, typically less than 24 hours. The rate of rise and fall for the lesser flood events (those peaking around 20,000 cfs) are fairly consistent. Although recording equipment malfunctioned soon after the peak of the February 1996 flood, this event appears to have been the largest in terms of peak magnitude, peak duration, and volume above flood stage.

Flood volumes are also noticeably similar for these events, with the exception of the November 29, 1995 flood event, which displays multiple peaks, presumably owing to storm surges producing overlapping flood hydrographs. Multiple peaked flows are significant to streambank erosion because of the increased incidence of wetting (Knighton, 1998).

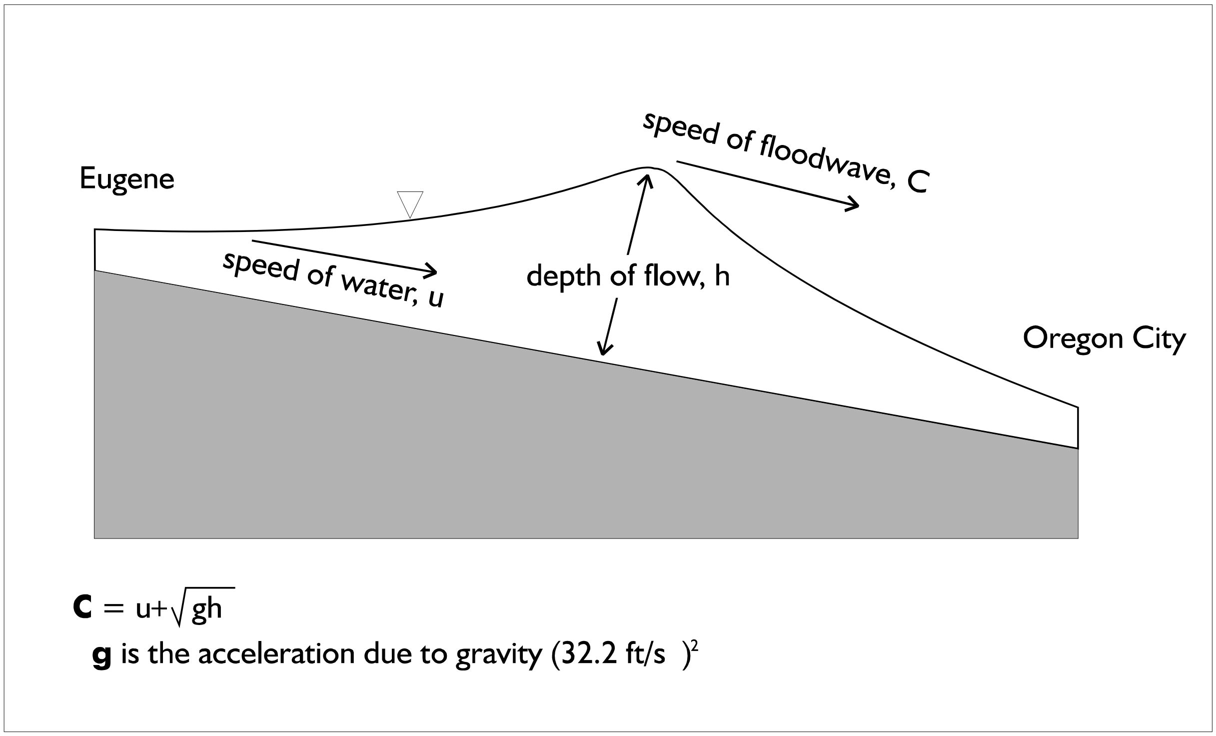

Figure 6-3-3. Flood Wave Propagation. Source: Coulton *et al.*, 1996

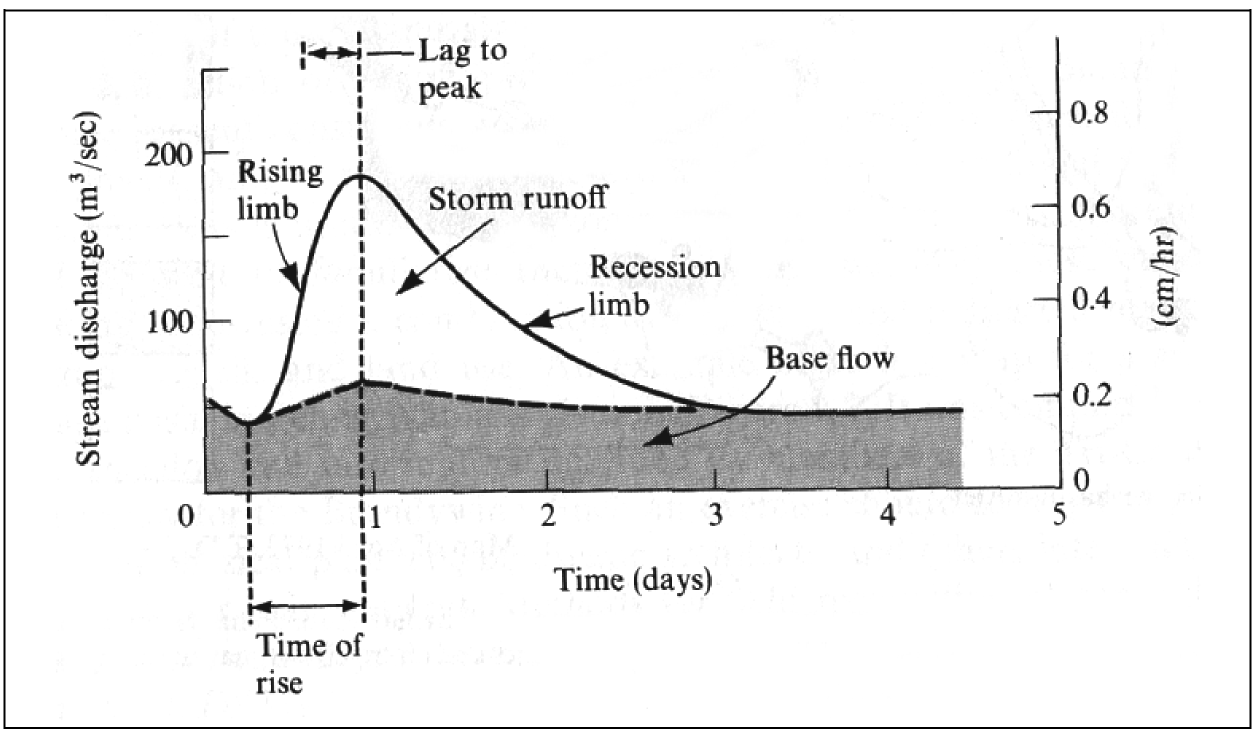

Figure 6-3-4. Hydrograph of Streamflow in Response to a Rainstorm from a 100-sq-km Basin.
Source: Dunne and Leopold, 1978

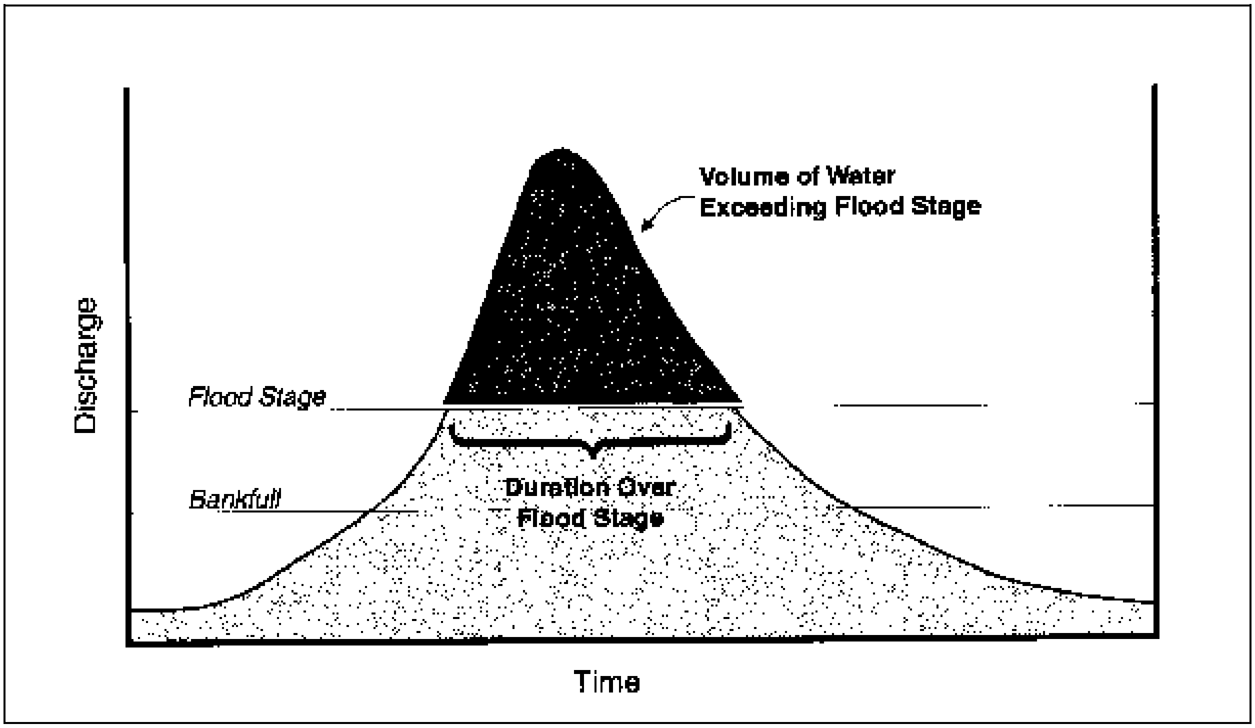

Figure 6-3-5. Relationship between flood stage and flood volume

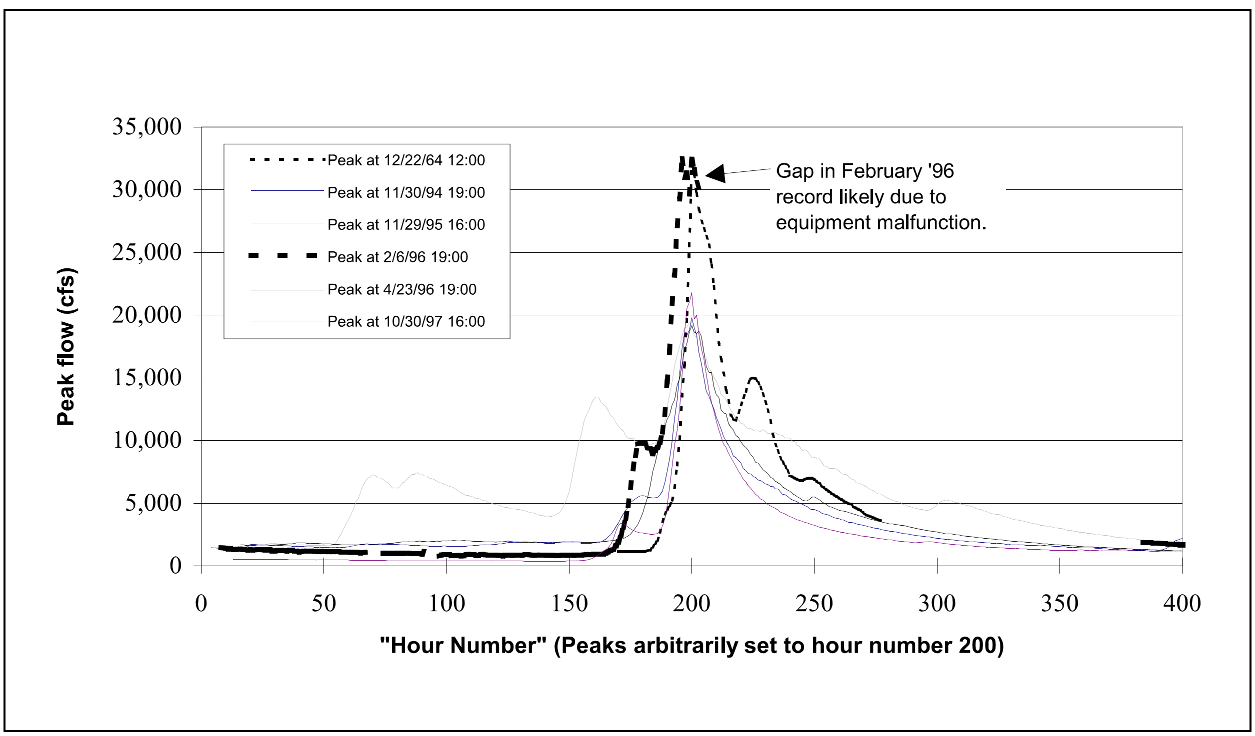

Figure 6-3-6. Peak Flows of the Wilson River, October 1994 through April 1998, and December 1994

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6.4 River and Tidal Hydraulics

Hydraulics, simply stated, describes the work done by water. A major component of river hydraulics is sediment transport -- the movement of material by water. The mechanisms by which sediment is moved are different in different areas of the landscape. Uplands are generally areas where sediment is picked up. Lowland valley floodplains are areas where deposition and sorting take place. Estuaries are subject to tidal fluctuations, creating a unique transportation mechanism. This section covers sediment discharge, flood stages, overbank flooding, sea-level change, tide gauging, tidal datums, stillwater elevations and coastal flooding, tidal prism relationships, and head of tide.

6.4.1 River Flood Stages and Overbank Flooding

■ Objectives

The objective of this assessment was to compare river stage forecast data with recorded peak steamflow data to evaluate the relative severity, magnitude, frequency and duration of historic overbank flood events in the Tillamook bay basin.

■ Methods

River stage descriptions for the Wilson river were obtained from the National Weather Service River Forecast Center in Portland (Figure 6-4-1). Gauged flood flows were correlated to these river stages using the stage discharge relationship provided on the most recent USGS rating table (stage-discharge relationship) for the gauge (Rating Table No. 15, November 11, 1995). For example, the 14-foot river stage corresponding to moderate flooding was compared to the rating table, and this stage was associated with a river discharge of 15,790 cfs. A similar method was used to develop relationships for the other river stages shown in Figure 6-4-1.

An estimate of the duration of flooding -- days above flood stage -- on a water-year basis (October through September) was made by determining the number of mean daily flows at the Wilson River stream gauge that exceeded the NWS-designated flood stage discharge of 13,200 cfs (Figure 6-4-1). This evaluation assumes that flows exceeding the NWS flood stage discharge result in overbank flows in the lowland valleys. Hourly flows at the stream gauge were then evaluated to determine the total days of overbank flows within each water year (Figure 6-4-3). The same assessment was made for hourly flows from 1994-1998 (Figure 6-4-6).

■ Discussion

The flood stages described in Figure 6-4-1 are shown together with annual peak discharges for the period of record of the Wilson River gauge in Figure 6-4-2 to provide an assessment of the frequency and magnitude with which flood events exceeded the various flood stages.

Figure 6-4-3 indicates that brief periods of overbank flooding (up to one day) appear to have occurred on a more frequent basis throughout the early part of this century and up to the mid-1970s. The clusters of fairly regular annual flood pulses from 1942 to 1950 and 1961 to 1967 occured during a general period of wet, cool weather along the Oregon coast, and soon after the major burns in the Tillamook Basin. Both these conditions would tend to increase the potential for runoff and flooding. Since the 1970s, annual overbank flooding exceeding a day in duration appears to be more frequent, with durations up to three days. This may be an indication of more variable climatic conditions combined with upstream land use practices that are causing runoff to become more “flashy” and less regular in occurrence.

Figure 6-4-4 shows the distribution of hourly streamflows for the Wilson River stream gauge, and the frequency and duration of flows exceeding flood stage within the water years 1995 into 1998. The "pulsing" nature of streamflow is readily apparent in this figure, as represented by the dark spikes of hourly flow through the winter months. Overbank flows do not occur on a continual basis, but rather expand and retreat across the floodplain during flooding and drawdown. Floodplain lands within this extent of flood inundation experience high turnover rates of organic matter and nutrients (Bayley, 1995) and are important habitats for fish and wildlife. Figure 6-4-4 also shows that most of the annual pulsing in water level occurs below flood stage. This points to the importance of the riparian corridor along rivers channels, and the river banks themselves, as highly productive portions of the river system where the most dynamic interaction between land and water occurs.

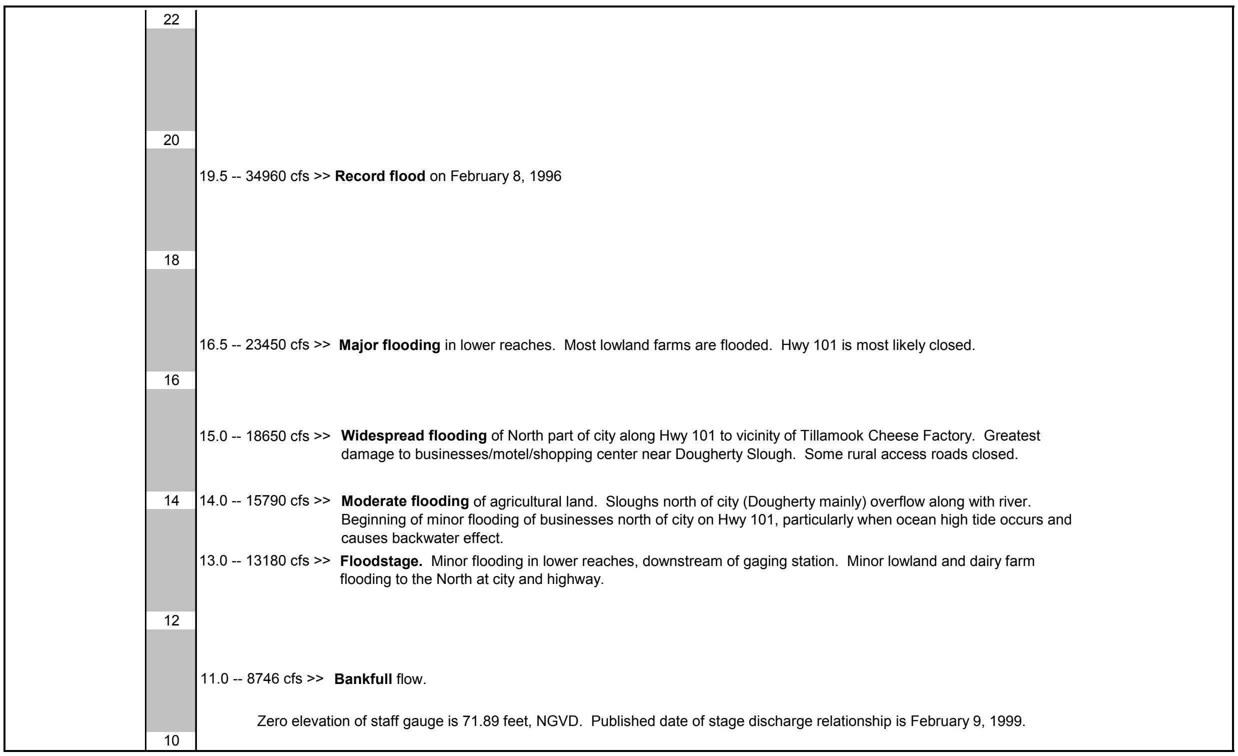

Figure 6-4-1. Wilson River Flood Stages Source: NOAA, 1999

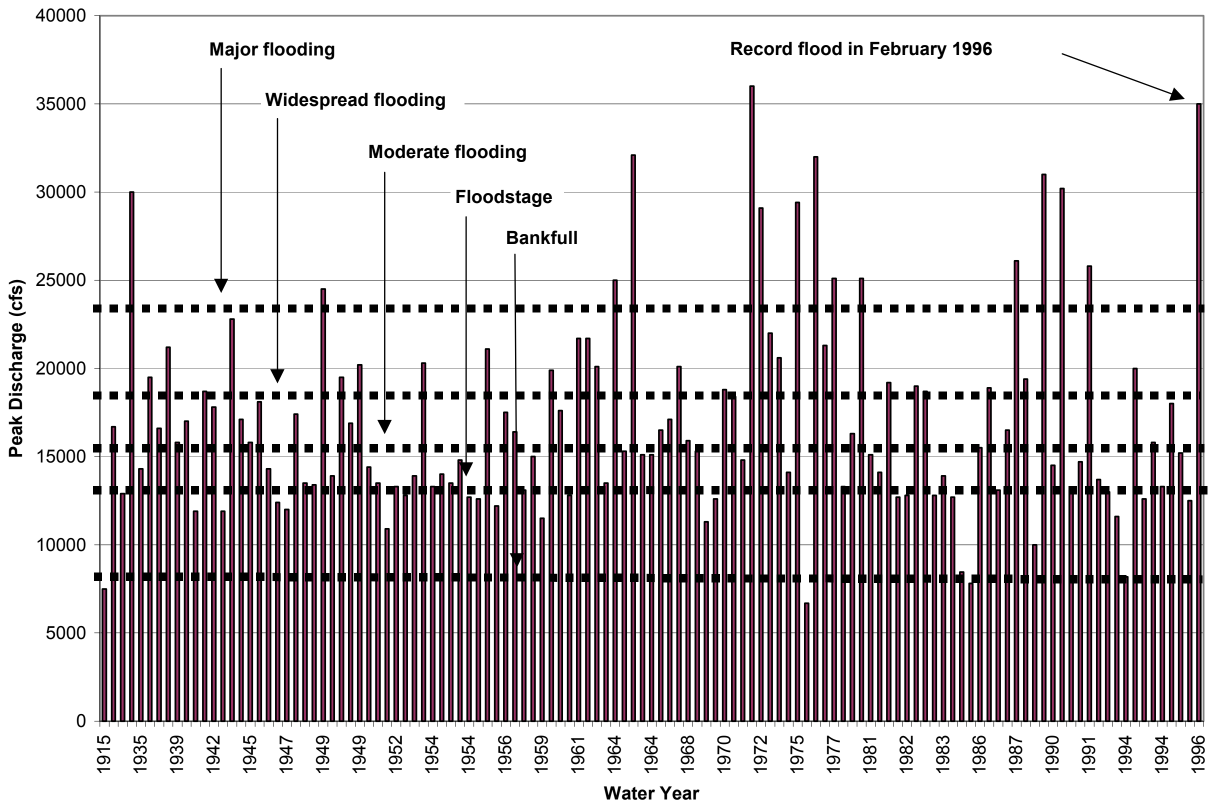

Figure 6-4-2. Wilson River Annual Peak Discharges in Relation to Flood Stages

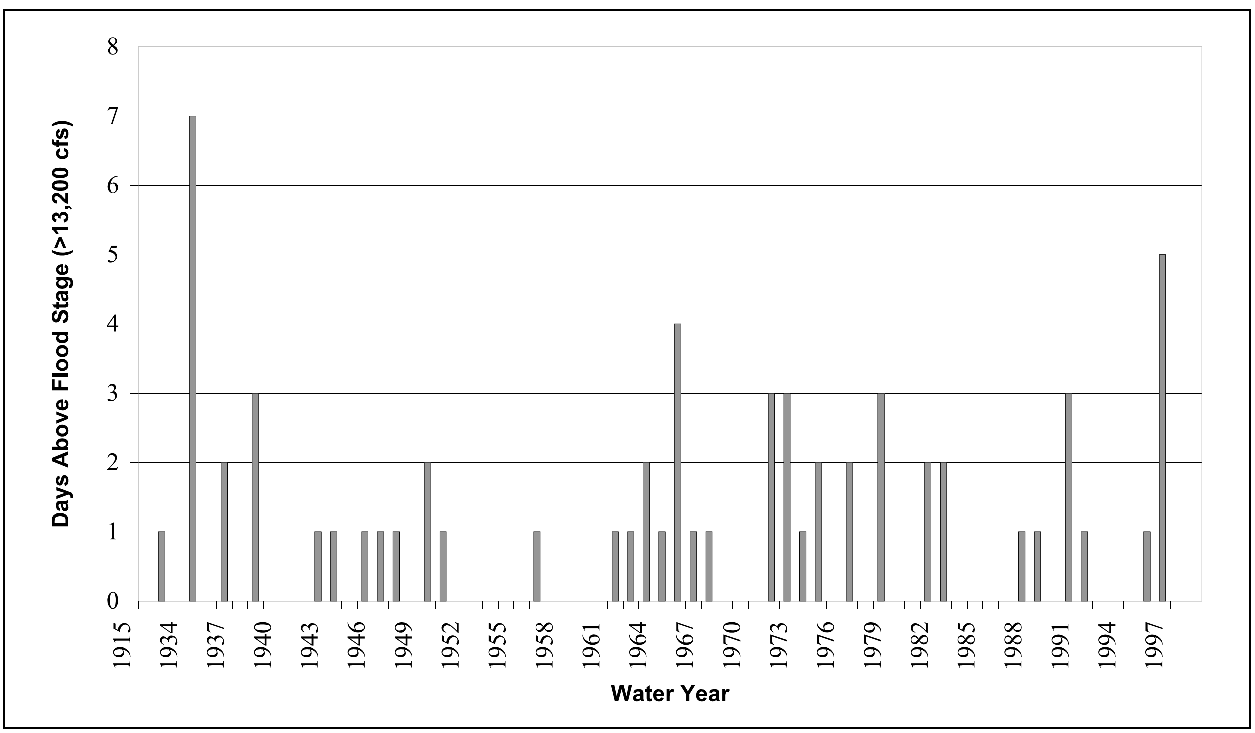

Figure 6-4-3. Days above Flood Stage for Historic Wilson River Floods

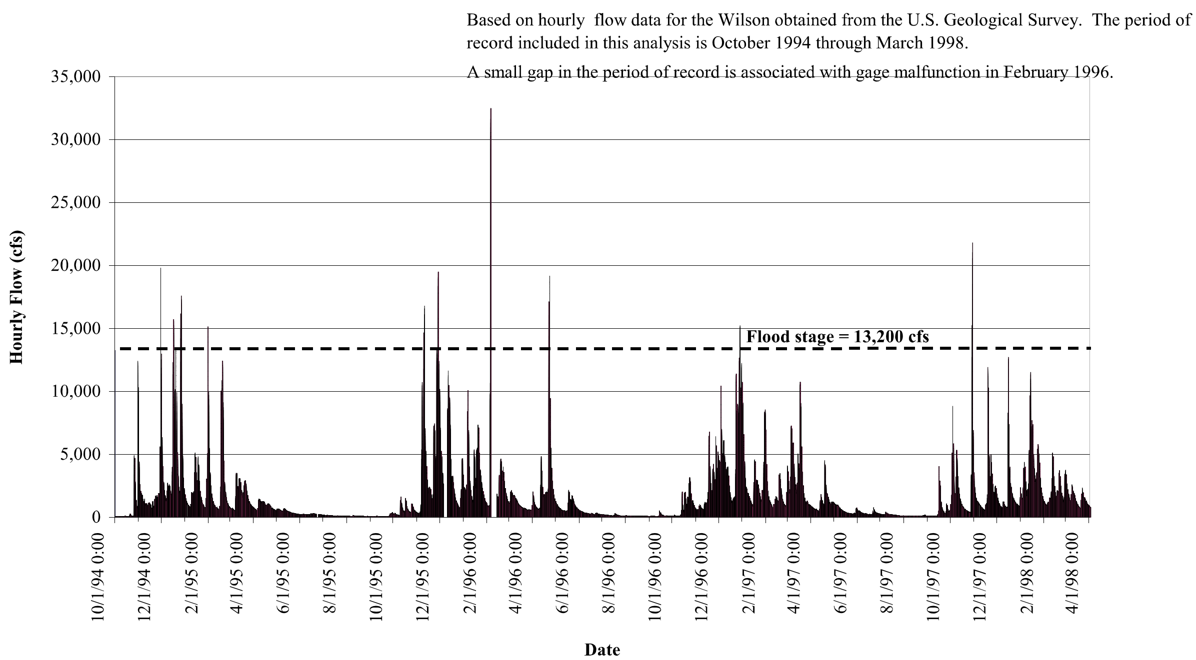

Figure 6-4-4. Hourly Flows about Flood Stage for Wilson River

6.4.2 Lowland Valley Flood Characteristics

■ Objectives

Flooding is a dynamic physical process that can be extremely complex in lowland valley floodplains where flood flows combine and interact with the tides. The best method to describe lowland valley flood characteristics is through the use of computer models that can evaluate complex changes in water level and, with some models, the two-dimensional flow patterns of the flood waters. The Tillamook Bay lowlands were modeled in the 1970s as part of a FEMA flood insurance study using a one-dimensional steady state model (HEC-2). However, since the modeling was done about 25 years ago, it was not possible to retrieve from archives. The objective of this assessment was therefore to determine general flood characteristics in the lowland valley using available information and simplified methods.

Since many floodplains in Oregon have been evaluated by FEMA, a simplified method was devised to utilize FEMA data to identify flood characteristics. This method involved using estimated FEMA flood elevations and discharges, and delineating land drainage patterns. These methods should not replace, but rather complement, additional information that may be available from the application of computer models that can better describe the dynamic characteristics of flooding.

■ Methods

Flood elevations from the FEMA flood profiles were compiled at key locations along each lowland mainstem river reach, typically at bridge crossings that were readily defined on the profiles. In the absence of FEMA data, high water marks from flood events can also be used to help define the maximum floodwater surface elevation. FEMA flood profiles show water surface elevations for the 500-, 100-, 50-, and 10-year flood events. From a flood management and aquatic ecology standpoint, the 10-year event is of more interest because of its more frequent occurrence. Water surface elevation contours for the 10-year event were sketched by interpolating between elevation locations (Figure 6-4-5).

Stream power values were estimated for the 10-year flood event in the lowland river reaches using FEMA flood insurance study data. FEMA flood profiles were used to determine elevations at key locations along the rivers, and published 10-year flood discharges were associated with these elevations. Flood elevations, and distances between the elevation locations, were used to estimate slopes across the 10-year flood water surface. The slopes were then used to roughly estimate stream power for the 10-year flood event. Stream power is a measure of a river's ability to do work, i.e., to move sediment and erode streambanks. Stream power was estimated using the expression $P = \gamma QS$, where γ is the unit weight of water (generally 62.4 pounds per cubic foot), Q is the discharge, and S is the water surface slope. The average of all values was determined, and stream power values were rated as low or high, based on whether they fell below or above the average value. Figure 6-4-6 provides a general indication of the lowland river reaches where stream power is relatively high for the 10-year flood event.

After a flood peaks and begins to recede, land drainage patterns begin to exert control over flood flow characteristics. Drainage patterns were generally identified by sketching flow arrows on a topographic map within the FEMA 100-year floodplain boundary. In this case, the topographic work map used to develop the FEMA floodplain was available and used; however, any large-scale map may be used in this kind of effort. Flow paths can also be observed from historic maps and aerial photographs. Figure 6-4-7 shows generalized land drainage patterns, and provides an indication of flow around floodplain encroachments and cross-flow between the lowland river channels.

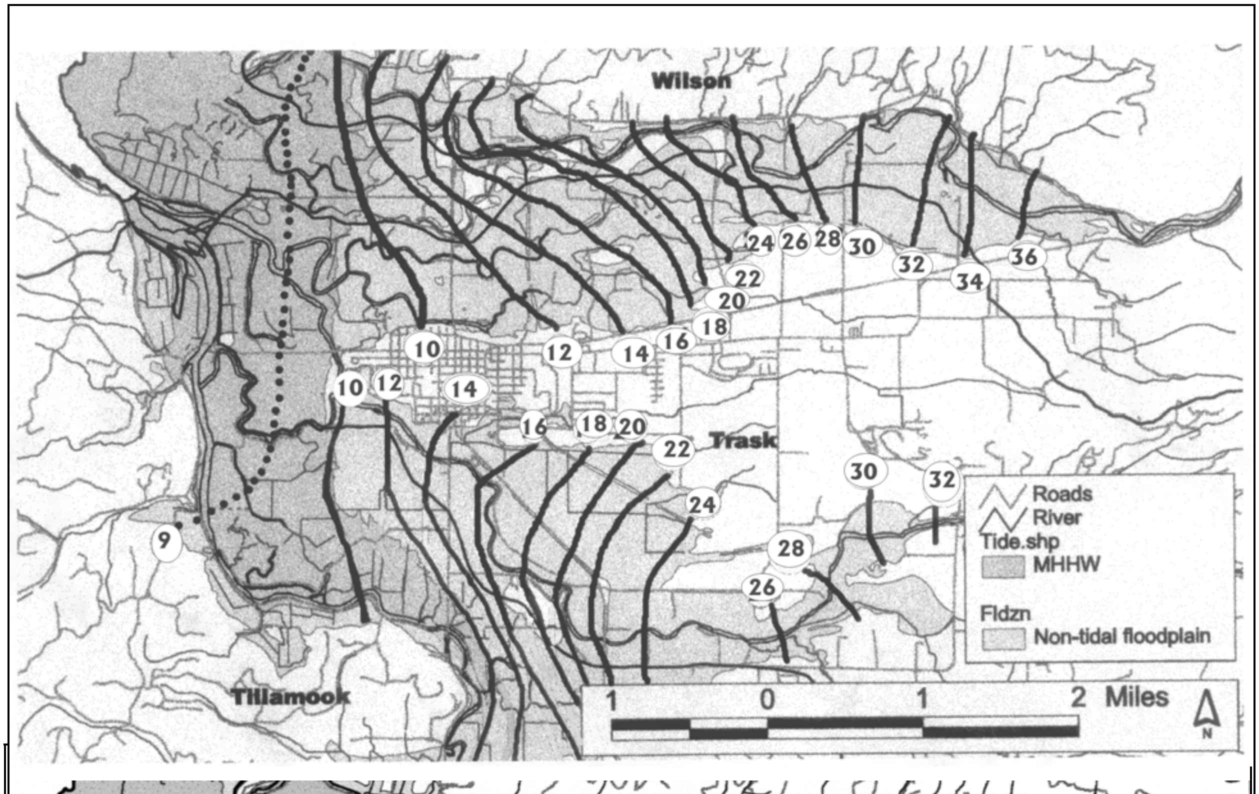

Figure 6-4-5. Generalized 10-Year Flood Water Surface Contours

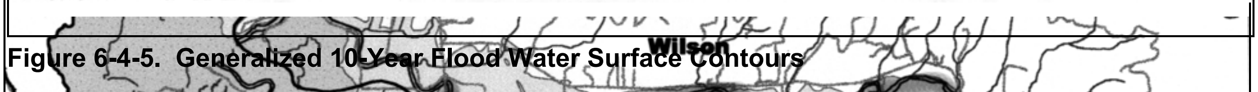

Figure 6-4-6. Relative Lowland Floodplain Stream Power Estimates

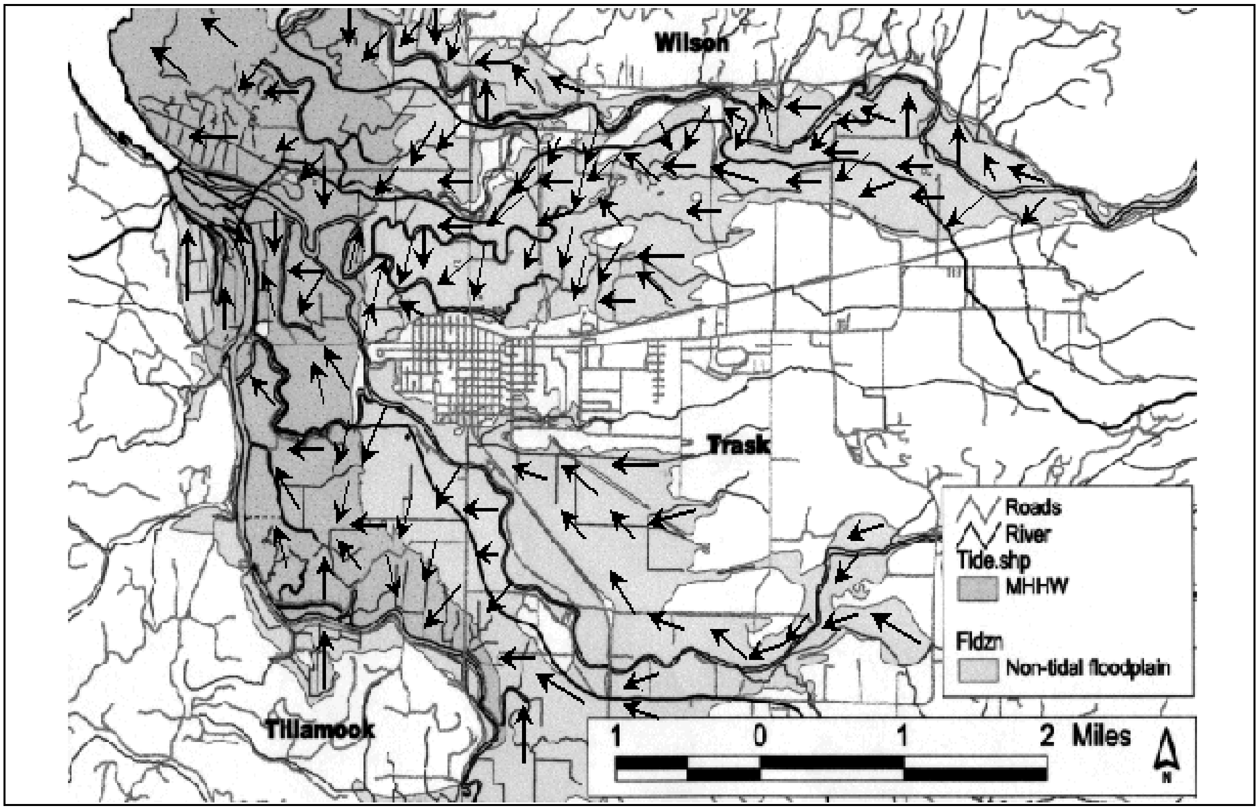

Figure 6-4-7. Generalized Land Drainage Patterns

In lieu of the use of a computer model to simulate the complex characteristics of flooding, simplified methods were used to describe lowland valley flood characteristics. The 10-year flood water surface elevation contours provide a glimpse of a hypothetical flood condition, where steeper slopes indicate higher energy flows, and flow directions can be estimated perpendicular to the contours. Based on this simplified assessment of the 10-year flood event, the contours indicate that overbank flood flow paths may be significantly different from river channel alignments. The bulk of the floodwater from the Wilson River flows in a southwest direction towards Dougherty and Hoquarten Sloughs. Trask River flows trend due west into the Tillamook River (Figure 6-4-5). Flood management efforts should address high energy flow areas, where flood gradients are steeper, by minimizing floodplain encroachments that may lead to or worsen land and riverbank erosion. Strategies should be developed that accommodate the direction of overbank flood flows between river and slough channel systems.

Estimated stream power values were lowest in the Tillamook River system and highest in the Wilson River system. Figure 6-4-6 shows the distribution of high and low power values for the lowland valley. Estimates indicate that a majority of the Wilson River reach upstream of Highway 101, and portions of the Kilchis and Trask River reaches in the vicinity of Highway 101 have high power values. Encroachments along these reaches, such as bridges and levees, should be evaluated carefully, and flood management strategies should be considered to reduce floodwater gradients and increase conveyance.

Land drainage patterns provide an indication of the effects of natural and human encroachments on floodplain water flow and cross-flow between river channels. The drainage patterns generally support the patterns observed from the 10-year flood contour mapping. One of the important items gained from this exercise is the identification of low points in the terrain, especially those at encroachments in the floodplain (Figure 6-4-7). Flood management efforts should prioritize the conservation or restoration of low elevation floodplain land areas where flood overflow would occur and recede, in order to minimize the duration of floodwater inundation of other land areas used for farming and roads.

6.4.3 Tide Gauging and Tidal Datums

▪ Objectives

The tides play a significant role in flooding and in the evolution and sustenance of estuarine ecosystems in the Tillamook Bay system. The objective of this assessment was to document available tide gauge data and to develop relationships between these recorded elevations and local tidal datums, which designate significant ecological zones in the estuary and tidal river reaches.

▪ Methods

Tidal elevations have been monitored in Tillamook Bay very sporadically since the 1920's. Up to six tide gauges have monitored water elevations in the bay, with the gauge at Garibaldi operating with the longest continuous period of record (Figure 6-4-8). Statistical data for tidal elevations for the bay are dependent on the Garibaldi gauge due to the lack of a continuous period of record for all the other gauges. The Garibaldi gauge was in operation between 1972 and 1981 and has recently been reactivated as part of a TBNEP initiative.

Monthly high and low tide elevations were obtained from NOAA for the period of record of the Garibaldi gauge. Hourly tide elevations are also available from NOAA, but these data were not used in this level of assessment. Predicted high and low tides were obtained using the nautical software Tides and Currents, version 2.5. This software provides summaries of astronomical tides. The gauged monthly high tides and astronomical monthly high tides were compared (Figure 6-4-9) to assess the magnitude and trend in differences between predicted and actual tide elevations. Predicted tide elevations were selected for those dates and times most closely matching the date and time of the gauged high tide.

Monthly high tide data were also plotted against estimated tidal stillwater elevations and the MHHW and MLLW tidal datums to assess the relationship of recorded tidal elevations to these estimated values. These tidal datums represent the average height of the high and low tides observed over a specific time interval.

Guidelines for the restoration of estuarine systems in the Pacific Northwest have been developed related to landscape principles. Two approaches consider the habitat requirements of birds and juvenile salmon (Shreffler and Thom, 1993). An example of the feeding guilds of waterbirds is shown in Figure 6-4-11, related to tidal datums. Habitat zones for waterbirds are determined by elevation, tidal inundation frequency, salinity and sediment conditions, which determine the arrangement of intertidal food organisms.

▪ Discussion

As expected, gauged tidal elevations are typically higher than predicted values (Figure 6-4-9). Elevation differences range from 3.7 feet to zero. Gauged tides have been lower than predicted tides sporadically, but in no instance have the monthly high tides been lower than the MHHW tidal datum.

In Tillamook Bay, discrepancies between predicted and recorded tides at Garibaldi may also be attributed to navigation improvements at the bay entrance and channel that possibly affect the tidal response of the bay (Levesque, 1980).

The normal tidal range within the approximately 9,000 acre bay is about 7.5 feet with this range attenuated to about 5.2 feet at the southern end of the bay, the farthest location from the channel entrance. Diurnal tide extremes of up to 13.5 feet MLLW have been recorded, with a highest observed mean tide at the Garibaldi gauge of 14 feet, MLLW (Levesque, 1980).

Although the ecological focus of floodplain and tide marsh restoration tends to be on salmon, consideration should also be given to habitat changes for other species, such as waterbirds. The use of tidal datums in restoration planning can provide a common basis from which to compare estuarine habitats and multiple species benefits.

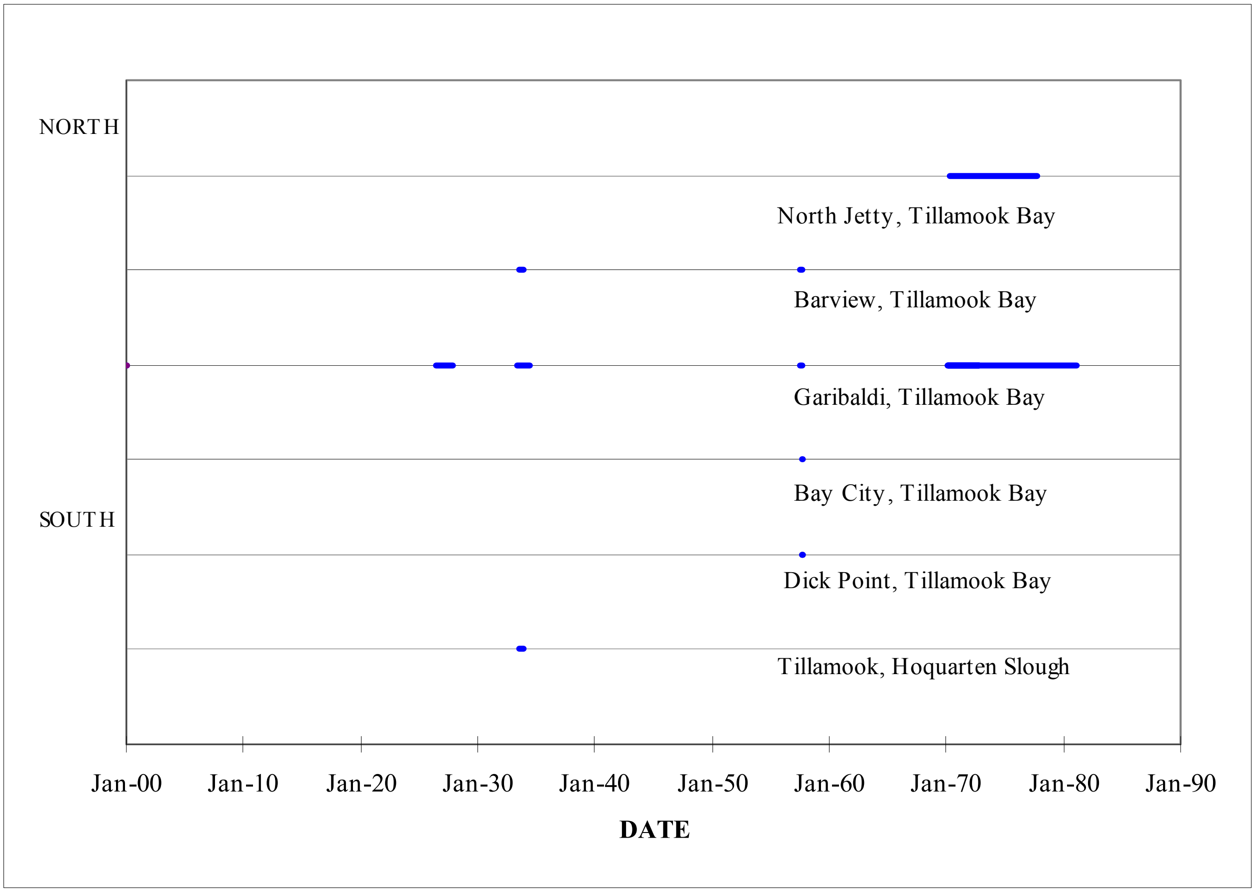

Figure 6-4-8. Periods of Record for Tide Gauges in Tillamook Bay

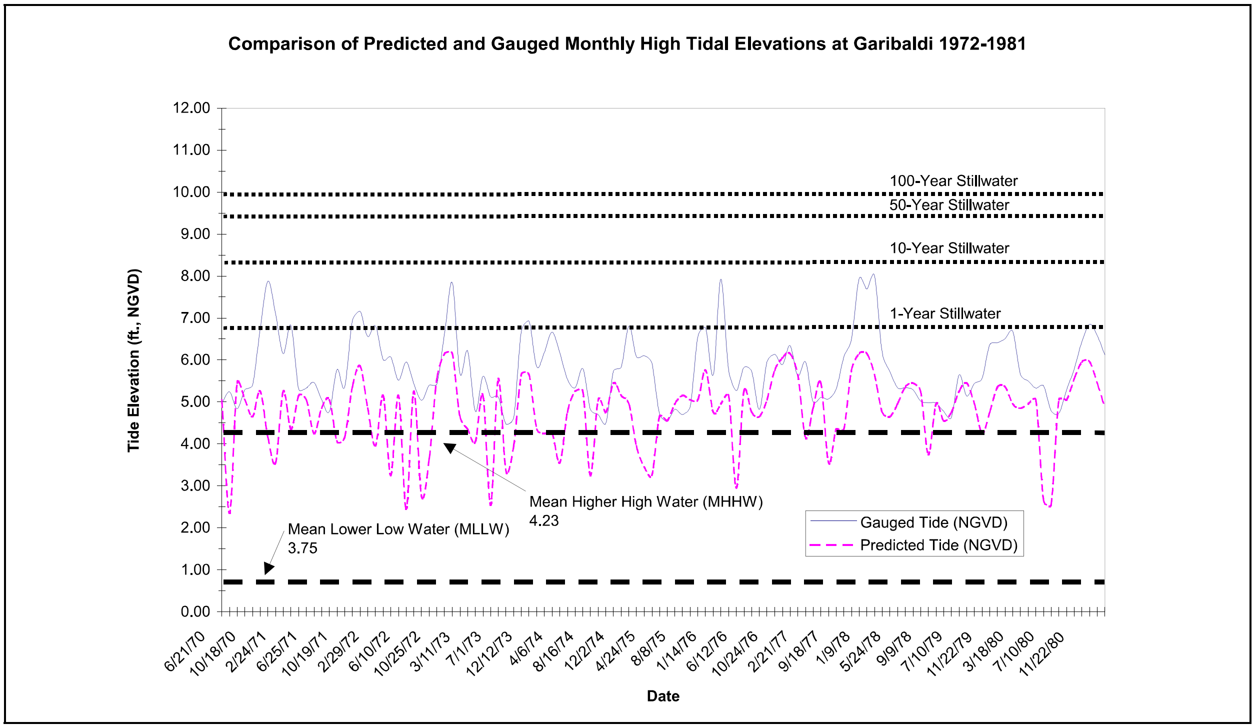

Figure 6-4-9. Comparison of Predicted and Gauged Monthly High Tidal Elevations at Garibaldi 1982-1981

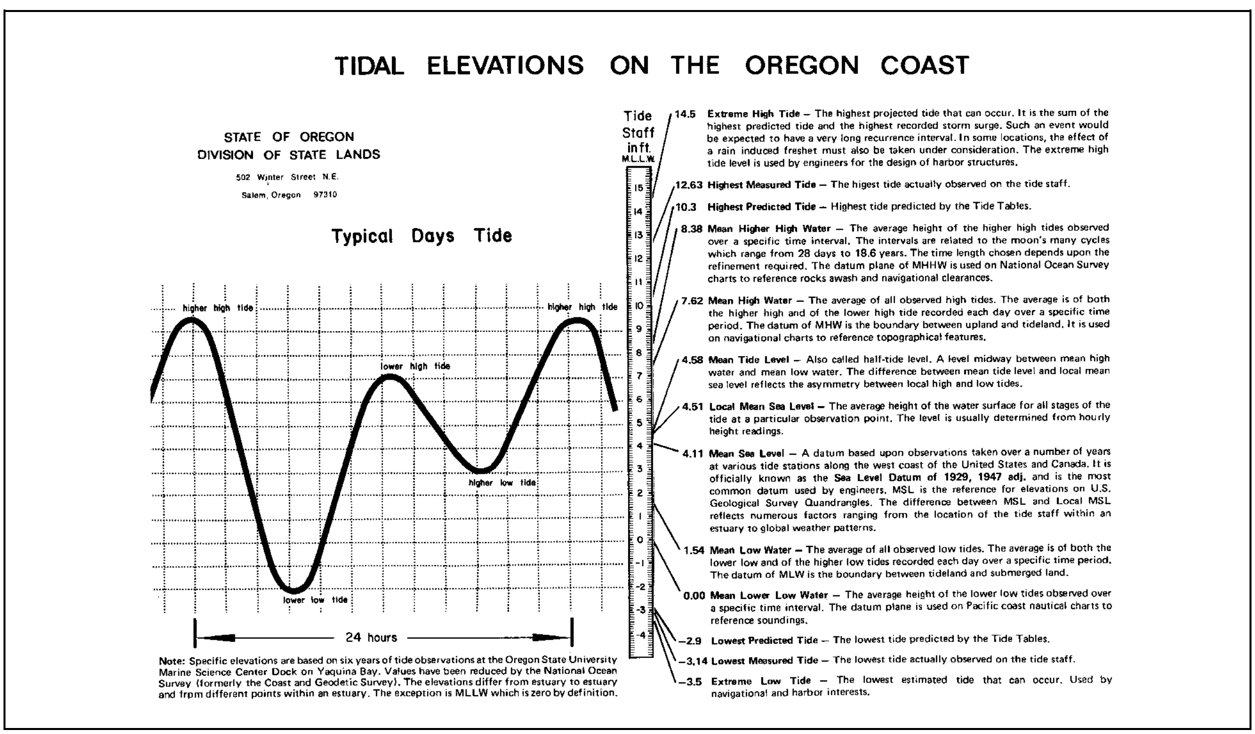

Figure 6-4-10. Tidal Elevations on the Oregon Coast Source: ODSL, 1973

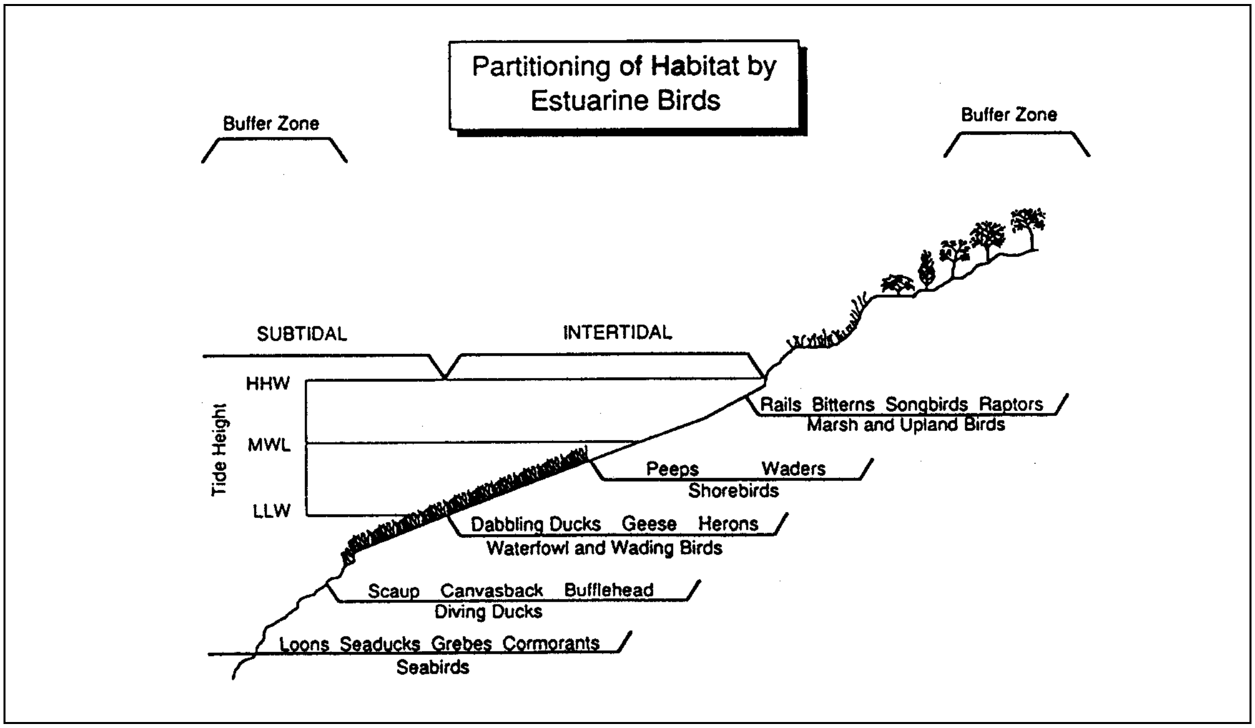

Figure 6-4-11. Partitioning of Habitat by Estuarine Birds According to Group-Specific Feeding Requirements Source: Shrettler, 1992

6.4.4 Tidal Prism Relationships

■ Objectives

Tidal prism refers to the volume of water contained between the tidal datum planes of Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) for a given area, such as Tillamook Bay. It represents the volume of water that is exchanged during the typical half-day tide cycle. The ebb and flood movement of this volume of water provides energy to the estuary system, producing significant forces that shape the morphology of bay entrance channels--the hydraulic connection to the ocean--and tidal slough channels--the inland expression of the estuary system on the lowland valley floor. The objective of this assessment is to establish the importance of tidal prism in the management and restoration of estuary systems, and to show the relationships between tidal prism and morphological features of the estuary system.

■ Methods

Available information on tidal prism relationships pertinent to Tillamook Bay were collected to provide background for the development of management strategies for the estuary system. Figure 6-4-12 provides a schematic depiction of a tidal prism volume and its relationship to the area of a bay entrance channel below mean sea level (MSL). The relationship between tidal prism and bay entrance channel area is further illustrated for the major Pacific Coast bays, including Tillamook Bay, in Figure 6-4-13.

The tidal prism relationship to channel area and hydraulic depth (channel area divided by width) is shown for three Oregon estuaries (not including Tillamook Bay) in Figures 6-4-14 and 6-4-15.

Tidal prism relationships to slough channel morphology and marsh areas are not available for the Tillamook Bay estuary system. However, these data have been developed for estuary systems in the San Francisco Bay area and are presented in Figures 6-4-16 through 6-4-17 for reference. Tidal prism relationships to marsh area and slough channel width are useful for restoration design because these parameters can be readily determined from aerial photographs and maps.

■ Discussion

Tillamook Bay has a relatively large tidal prism compared to other bays on the Oregon coast (Figure 6-4-13). Figures 6-4-14 and 6-4-15 show trends in increasing channel depth and area, respectively, for increasing values of tidal prism. These data could be consulted if estuary management actions involve modifications to tidally-influenced channels. Modifications to channel areas and depths that fit the relationships shown may be more sustainable in the long term because the modified channel dimensions would conform to a naturally-occurring and self-correcting shape. Similarly, the design of management actions to modify or restore tidal slough channels (Figures 6-4-16 and 6-4-17) could use the general relationships developed for California slough channels as a guide, until a similar data set is prepared for Tillamook Bay or Oregon estuaries.

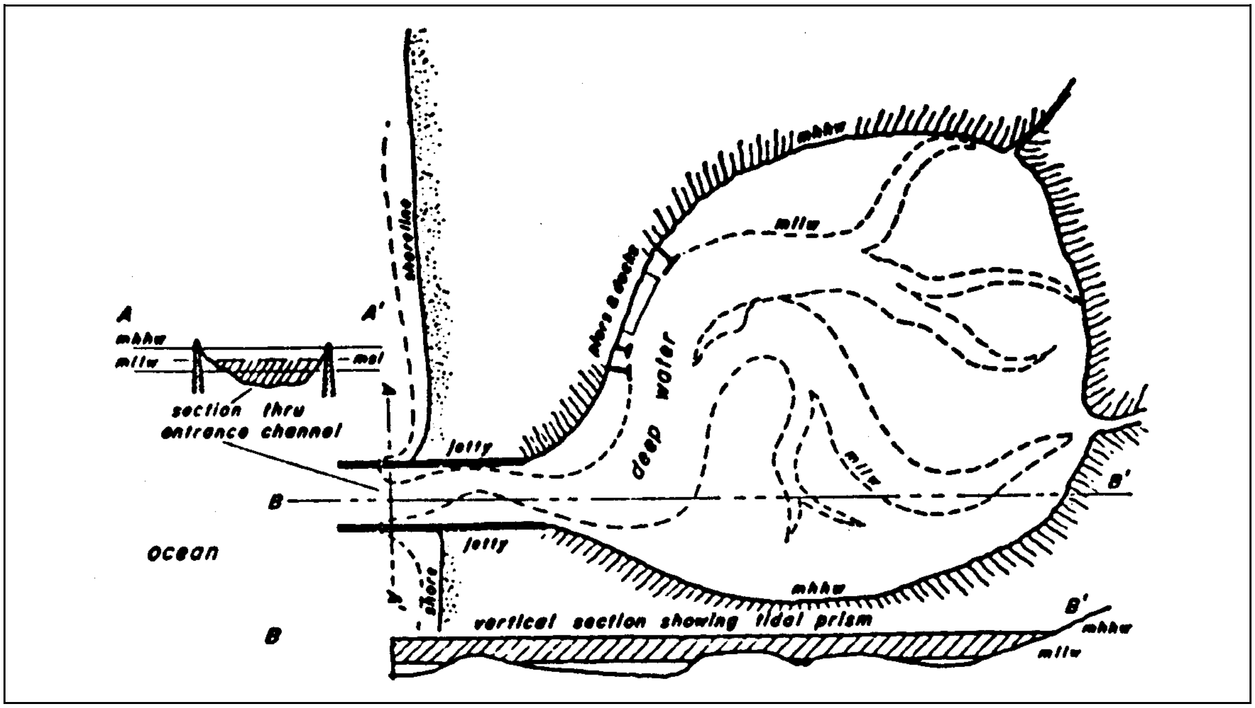

Figure 6-4-12. Bay Harbor Showing Tidal Prism the volume of water between (MHHW and MLLW Source: Bascom, 1964)

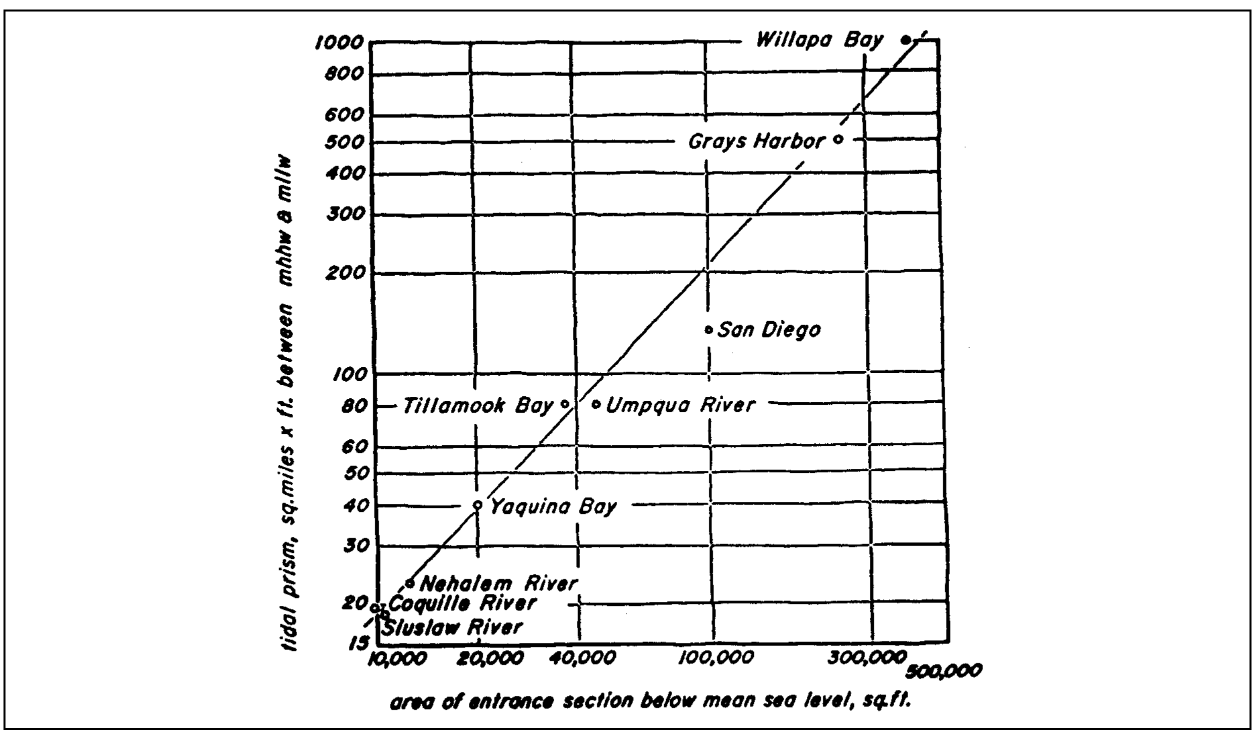

Figure 6-4-13. Relationship Between Tidal Prism and Entrance Section Source: Bascom, 1964

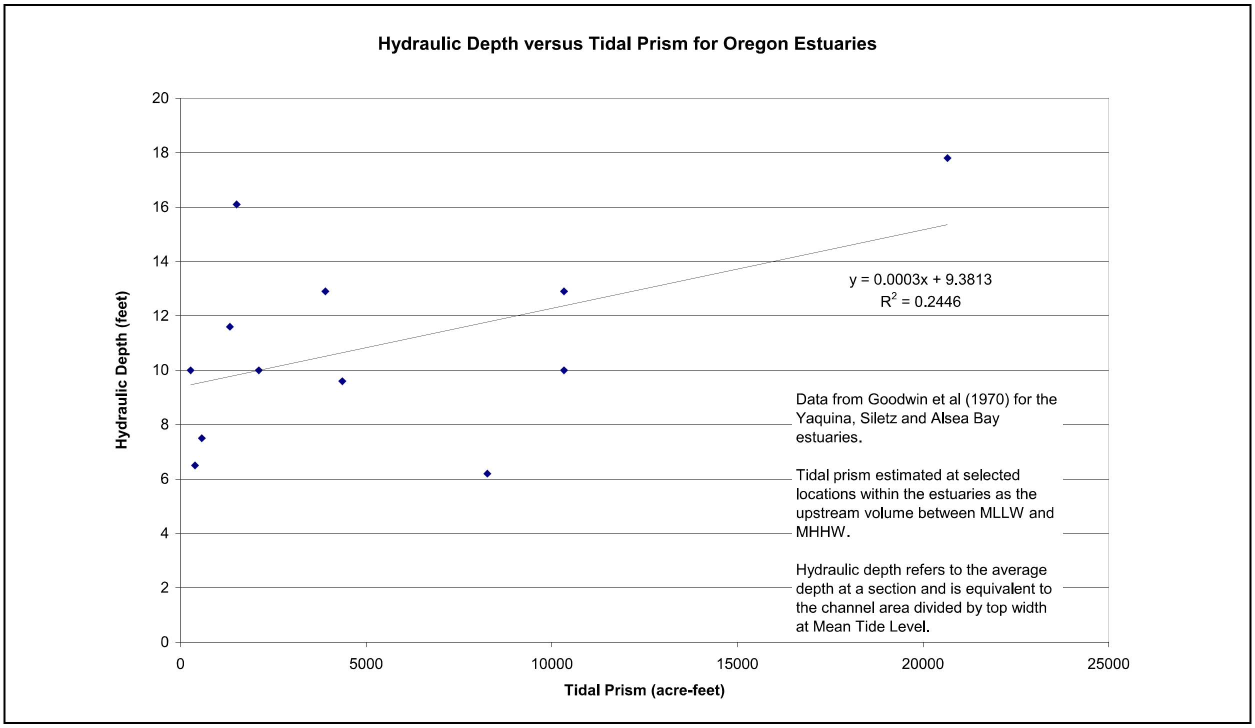

Figure 6-4-14. Tidal Prism versus Hydraulic Depth for Oregon Estuaries

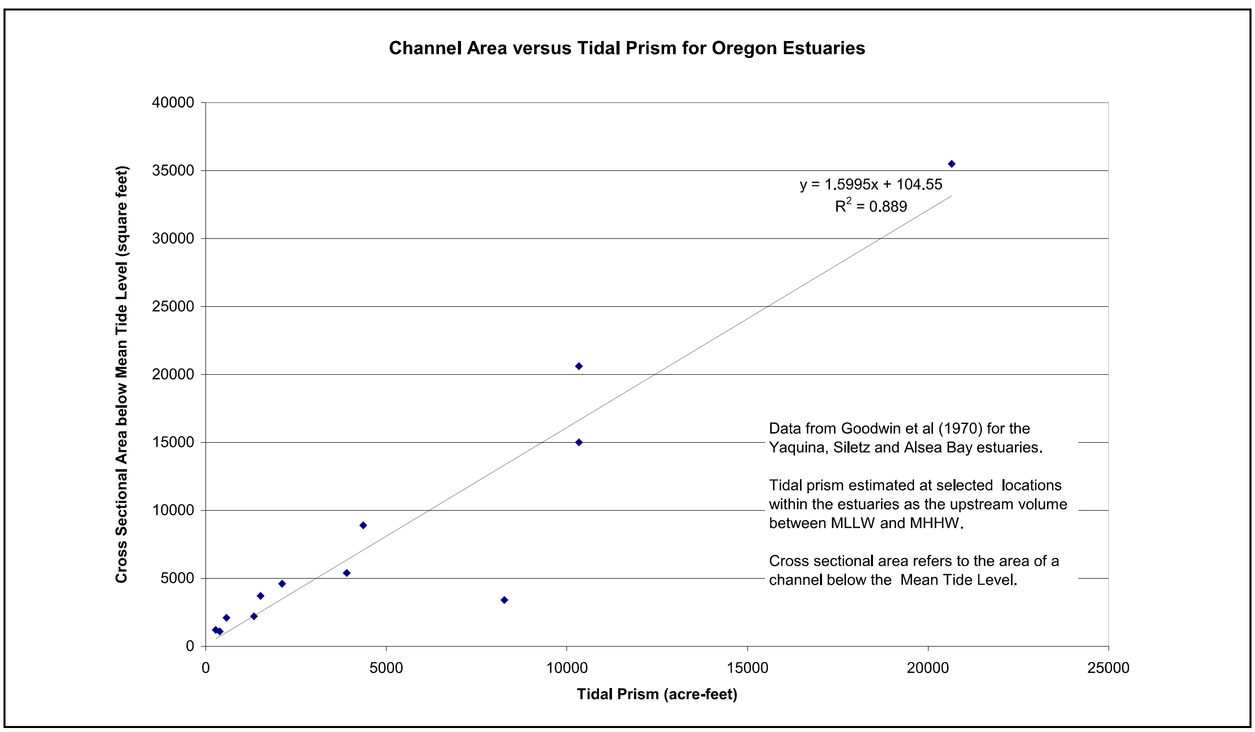

Figure 6-4-15. Tidal Prism versus Channel Area for Oregon Estuaries

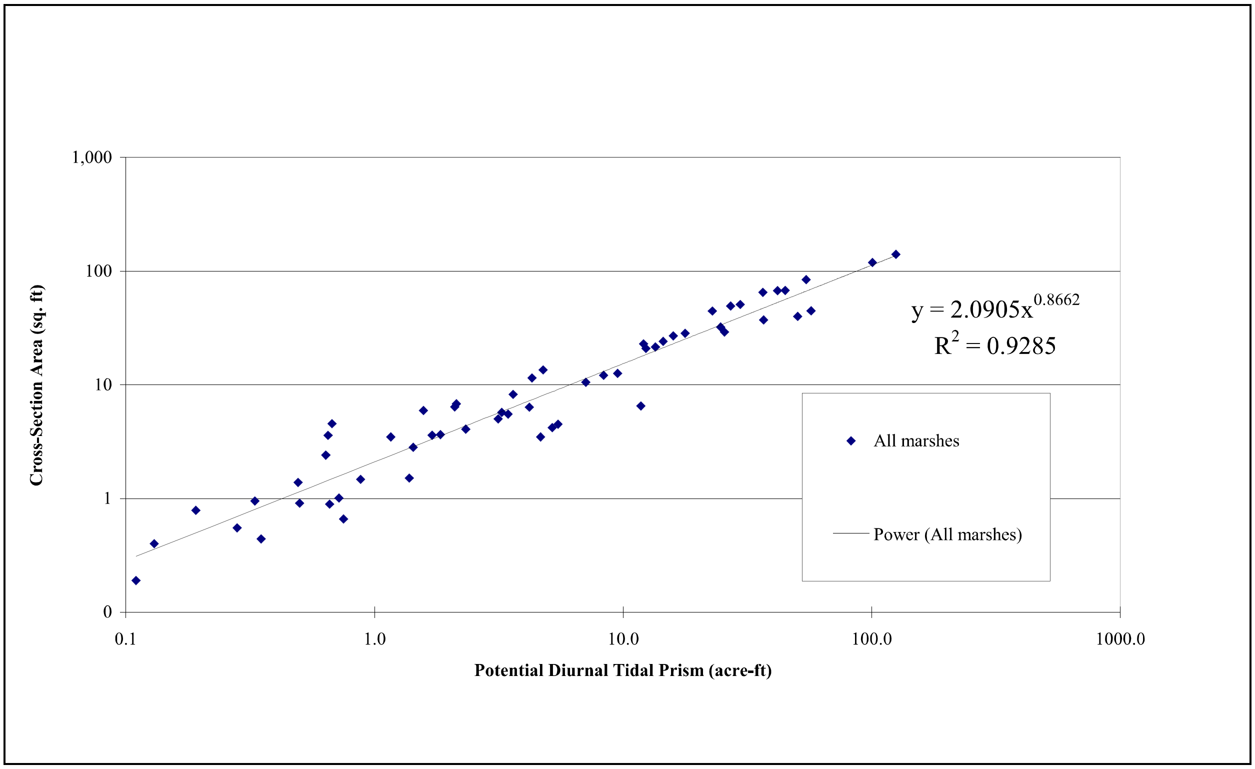

Figure 6-4-16. Tidal Prism versus Marsh Area in Tidal Sloughs Source:Coats et al., 1995

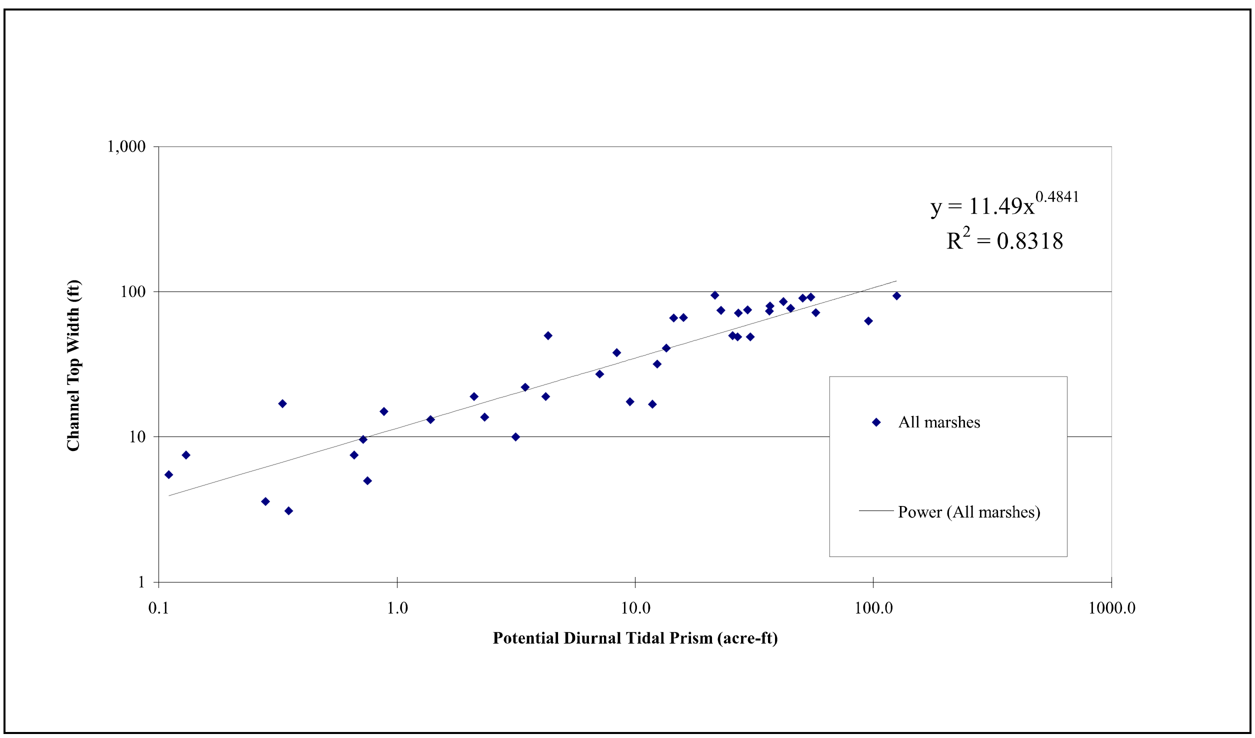

Figure 6-4-17. Channel Top Width versus Tidal Prism in Tidal Sloughs Source: Coats et al., 1995

6.4.5 Tidal River Reach Assessment

- **Objectives**

The preservation of tidal flows is important for maintaining water quality, protecting the stability of tidal channels, and sustaining tidal wetlands throughout the lowlands. Tidally-influenced areas are essential parts of the complete ecosystem of Tillamook Bay, providing habitat, refuge and rearing for several key species of fish and wildlife. Tidal influences in the lowland river reaches include tidal effects on water levels, as well as water quality effects due to salinity. The objective of this assessment is to define the spatial extent of tidal influences and to explore the relationship of these influences to a river management strategy.

- **Methods**

'Head of tide' is a colloquial expression for the furthest inland extent of tidal influence on river water surface elevation. The heads of tide for each of the five major rivers entering Tillamook Bay were identified from the Oregon Water Resources Department North Coast Basin map (Oregon Water Resources Department, 1992). Figure 6-4-18 shows the heads of tide for the Wilson and Trask Rivers.

The variation of salinity in lowland river reaches results, in large part, from the characteristics of flood tide (inland flow) and ebb tide (seaward flow), combined with river flow. During any given flood tide, the water entering an estuary is composed of a mixture of 'new' ocean water, and water which exited the estuary during the previous ebb tide and is now re-entering. This tidal exchange governs the overall flux of salinity and nutrients into and out of the river reaches and adjacent floodplain wetlands, but the distribution and concentration of salinity is strongly influenced by the mixing processes that take place throughout the system. Winds, waves, tides, and freshwater flows all contribute to the mixing of waters and help to distribute salinity within the lowland river system.

General aquatic subsystems have been defined for Oregon estuaries (Division of State Lands, 1984). In the lower reaches of the rivers, the division between brackish and freshwater subsystems has been generally located as shown in Figure 6-4-19 for the Wilson and Trask Rivers. The brackish subsystem is defined as having summer water salinities of 0.5 to 15 parts per thousand, compared to 0.0 to 0.5 parts per thousand for the freshwater subsystem (Division of State Lands, 1984).

Freshwater inflow to an estuary system provides another mixing mechanism and is a key component in estimating the boundaries of different plant community types. In addition to adding a continuously discharging flow component, freshwater flow may create density differences which result in stratification of the water column. A salt wedge may be formed which moves back and forth in the estuary with changes in tide (Figure 6-4-19), while turbulence at the interface produces mixing between the two layers. The mixing power produced by the tide depends on the density difference, the tidal velocity, the freshwater inflow and the estuary morphology, and in turn determines the density stratification which will be present in the estuary (Fischer et al., 1979). The degree of density stratification, in turn, dictates whether density-driven currents will significantly influence flows within the lowland river system. If stratification exists in the river channels and tributary sloughs, it is the lower-salinity water at the surface that flows out of the river channels and across the floodplain first, resulting in lower salinities than if the flows were fully mixed. This may be an important process if there is concern about maintaining a particular salinity range to favor or discourage certain types of plant communities.

Tillamook Bay is classified as a partially-mixed estuary (Fischer, 1989), where river flow discharges against a moderate tidal range (The Open University, 1989). Mixing of the water column is induced by turbulence created at the saltwater-freshwater interface and by friction along the bed of the bay and river channels. Additional mixing processes occur through wind and through circulation patterns in the Bay and tidal channels. A detailed description of these processes is provided in the literature, for example Fischer *et al.*, 1979, or the Open University, 1989. An illustration of water velocities and salinity concentrations in a typical partially-mixed estuary is shown in Figure 6-4-19. This figure also illustrates one reason for maintaining the natural geomorphic characteristics of tidal channels. If levees are constructed adjacent to the channels, or if the marshplain is filled, the flows over the marshplain may divert only surface waters, which will be fresh under stratified conditions. Under a different channel cross-section, the high tide may allow a mixture of fresh and saline water to flow across the marshplain. Thus, salinity structure and mixing processes are complex, influenced by river discharges, tidal flows, geomorphic characteristics of the tidal channel, and dominant physical processes. Prediction of hydroperiod and salinity in tidal channels and wetlands requires monitoring and/or the use of computer models.

■ Discussion

The significance and continuing loss of tidal wetlands in the western states has been well documented (Cowardin et al., 1979, Salveson, 1990 and Fretwell et al., 1996). The importance of taking a long-term planning perspective of tidal wetland preservation can be seen when considering the effects of sea-level rise (Houghton et al., 1990). The natural response of tidal wetlands to a sea-level rise would be to gradually migrate inland (French et al., 1995; Nuttle et al., 1997). However, if tidal channels have levees at their banks, there is no room for tidal vegetation zones to retreat. Further, the depth of the tidal channel cross-sections would be expected to gradually increase over time, resulting in bank stability problems. Planning to allow a buffer adjacent to tidal channels would therefore avoid channel stability problems and maintain some minimum acreage of intertidal habitat.

The tidally-influenced areas of the Tillamook Bay tributaries are the most dramatically diminished habitat type in the Tillamook watershed. These areas provide critical rearing and refuge habitat to several ESA-listed fish, and other organisms essential to the sustainability of the ecosystem. Functioning properly, they are likely to produce the most biomass per unit area (Tiner et al., 1984) of the entire basin, and form an important ecological link.

These tidally-influenced areas also correspond with some of the most expensive flood damages and channel protection activities, and highest revenue generated per unit area, in the basin. Restoration of these areas could provide several key flood reduction benefits for the people of Tillamook County, including:

- Diffusion of flood flow energy
- Reduction of wave action against levees and banks with the use of shallow vegetated buffers
- Improvement of water quality by removing nutrients and fine sediments

These tidally-influenced areas should therefore be prioritized for implementation of the IRMS, for both ecological and economic reasons.

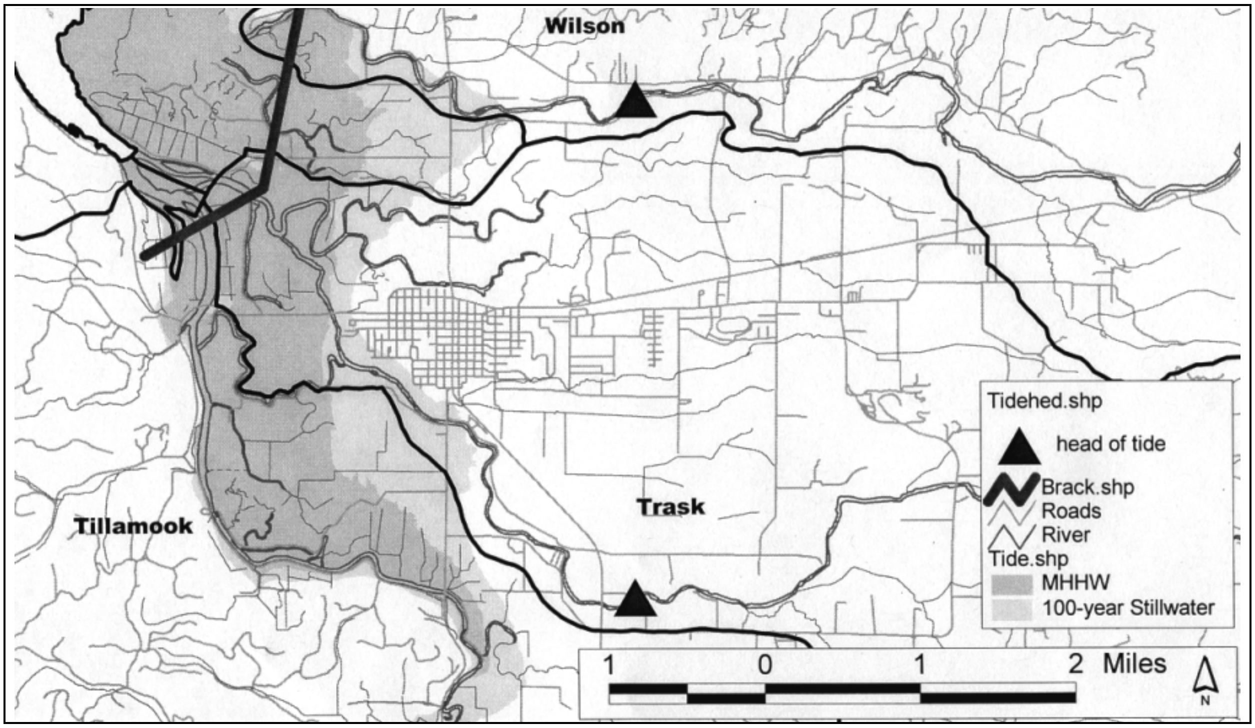

Figure 6-4-18. Tillamook Bay Lowland Valley Heads of Tides and Brackish/Freshwater Interfaces

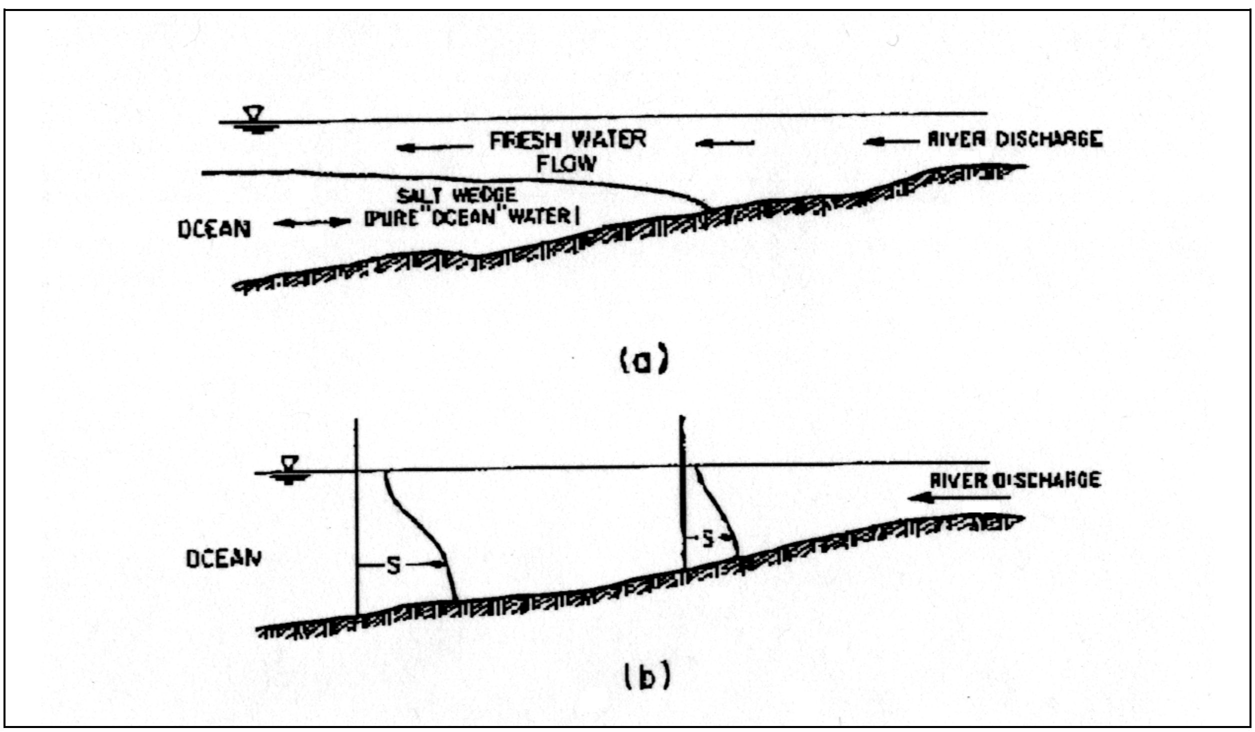

Figure 6-4-19. Salinity distributions in (a) a "salt wedge" estuary and (b) a "partially mixed" estuary

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6.5 Vegetation

The extent and growth of vegetation is dependent upon the interaction between land and water. Because of this interdependence, vegetative communities are often associated with specific types of physical processes. In this way, vegetation is an indicator of potential past and present river and tidal processes, and can be used to identify areas where those processes can be preserved or enhanced. In addition, the presence or absence of certain plant communities can guide decisions about what processes to preserve or enhance at a given location. This section describes vegetation zones in the Tillamook Basin, including the uplands, lowland valley floodplains, riparian areas, and tidal marshes. Historic forest and riparian conditions are reviewed, and characteristics of the large wood in lowlands are assessed.

6.5.1 Vegetation Zones of Tillamook Basin: Upland, Valley and Estuary

■ Objective

Using vegetation to coarsely categorize the landscape into zones provides a framework for understanding the processes at work in each zone, and for making spatially-specific planning-level recommendations. The objective of this assessment was to delineate the major plant communities in the Tillamook Bay Basin and assess the relative importance of the communities to fish and wildlife habitats.

■ Method

Written and mapped data were integrated to define meaningful delineations among the major vegetative communities in the Tillamook basin using GIS. The zones were designed to represent a correlation between vegetative community, slope, and the extent and duration of inundation by either fresh or salt water. In each instance, the zone represents a maximum spatial extent for each community (Figure 6-5-1).

■ Discussion

Two major upland vegetation zones occur in the Tillamook Bay Basin: the Sitka spruce (*Picea sitchensis*) forest zone and western hemlock (*Tsuga heterophylla*) forest zone. The Sitka spruce forest zone extends a few miles inland within the zone of tidal influence, and up the major river valleys to an elevation of about 500 feet (Franklin & Dyrness, 1988). The most common trees in this forest zone are Sitka spruce, western hemlock, Douglas fir (*Pseudotsuga manziesii*) western red-cedar (*Thuja plicata*), and red alder (*Alnus rubra*) (Franklin & Dyrness, 1988).

The western hemlock forest zone tolerates a mild, maritime climate, with a greater tolerance range of temperature and moisture than the Sitka spruce zone. In the Tillamook Bay Basin, the western hemlock/ Douglas fir forest zone occupies most uplands above approximately 500 ft. Major tree species in this zone include Douglas fir, western hemlock and western red cedar. Dominant early seral trees include red alder and big-leaf maple (*Acer macrophyllum*). These species typically occupy the zone near the channel because of their tolerance for high water table and for flooding. A diverse understory of shrubs, herbaceous perennials, annuals and grasses is complimented by high diversity in mosses, lichens and fungi for both forest types.

Lowland valley floodplain riparian forests are characterized by western red cedar, red alder, big-leaf maple and black cottonwood (*Populus trichocarpa*) (Franklin & Dyrness, 1988). A highly diverse understory of shrubs and herbaceous perennials is featured in floodplain plant communities. Topographic variation provides distinct habitat niches according to moisture regime and groundwater levels, from former channels such as oxbows and other floodplain wetland types to natural levees and alluvial terraces. These variations are important for fish and wildlife habitat.

Estuarine plant communities are distinguished by water regime. Tillamook Bay historically contained low salt (brackish) marsh below mean high water, high salt marsh above mean high water, swamp at higher tidal elevation, and wet meadows at the saltwater/freshwater interface. Brackish marshes support herbaceous plants such as pickleweed (*Salicornia virginica*), sedges (*Carex lyngbyi*), and bulrush (*Scirpus maritimus and americanus*). High salt marsh typically includes hairgrass (*Deschampsia caespitosa*), silverweed (*Potentilla pacifica*), Baltic rush (*Juncus balticus*) and meadow barley (*Hordeum brachyantherum*). Swamps have high water table and support woody plants such as willows (*Salix spp.*), alder, Sitka spruce, Douglas spirea (*Spiraea douglassii*) and herbaceous species. Wet meadows typically support grasses, sedges, and rushes, particularly slough sedge (*Carex obnupta*) and soft rush (*Juncus effusus*). Most of these have been converted to agricultural uses.

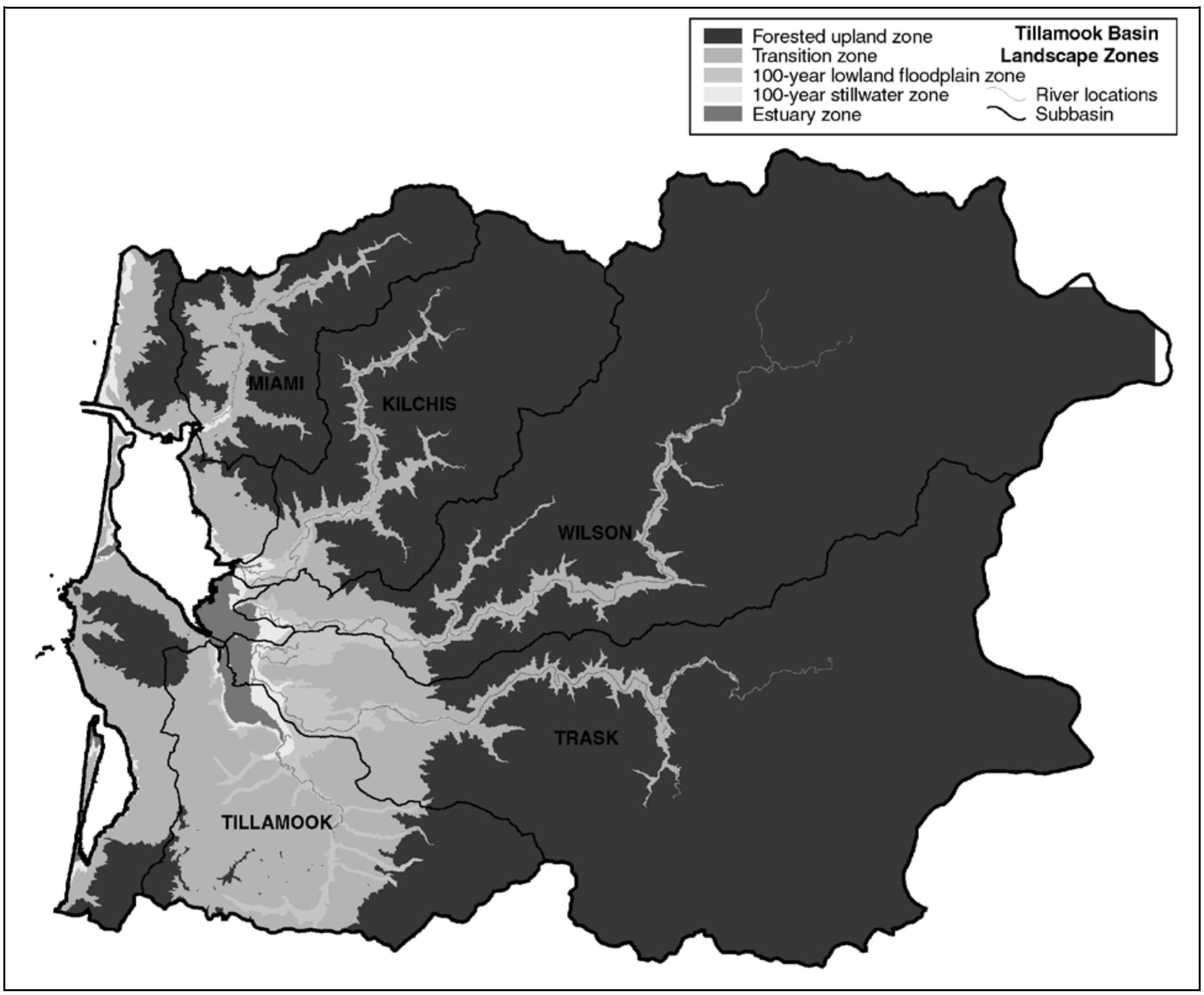

Figure 6-5-1. Vegetation Zones of the Tillamook Basin

6.5.2 Upland and Lowland Forest Historic Conditions

■ Objectives

Forest stand structure is important for landscape-scale processes, because large trees buffer the impacts of storms on the upland landscape, and moderate the force and speed with which rain and stormwater are delivered to the stream network. The structure and distribution of large wood in channels plays a key role in the stability of upland streams. Therefore, large trees are critical to the stability of the upland landscape and the rates of sediment delivery to the stream network. The objective of this assessment was to review available spatial data on landscape-scale vegetation structure and distribution, with special reference to human impacts on the historic landscape.

■ Methods

Available GIS data layers for the Tillamook Basin relevant to terrestrial analysis were reviewed. Few of the available data layers were reliable for site-specific analyses, but some did provide data for larger scale landscape analyses of historic change. The resulting maps provided a basic outline of forest cover changes in the basin uplands and lowlands from the 1850s to 1992, focusing on the presence or absence of forests and the distribution of mature forest (over 100 years in age).

■ Discussion

In the 1850s the Tillamook basin uplands were almost entirely covered by mature forest. Extensive burns (Figure 6-5-2) and human land use in the 1900s caused a changing mixture of mature and young forest in the uplands (Figure 6-5-3) (Williams/Cushman, 1999).

In the uplands by the 1890s a non-forest area increased in the west along upland/lowland border, while the small southern area that was non-forest in 1850 closed in. By 1890, most of the basin uplands remained mature forest. In 1920, young forests encroached even further on the last remaining non-forested areas. The portions along the shore of the border area remained non-mature forests. By 1945, drastic upland landscape changes included massive fires, which burned most of the basin's forest starting in the 1920s (Figure 6-5-3). Salvage logging operations began in areas affected by fires. Burned trees were seen as "wasted wood" and forests that were already damaged by fires were further devastated by salvage logging operations. By the 1950s, most of the mature forest was gone, and that which remained was in the southern portion of the basin. An area to the South and an area to the East along the border between the uplands and lowlands remained forested. By 1974-75, forests regenerated in a patchy, fragmented network. Young forests dominated the landscape with numerous small patches of mature forest throughout. In 1986, forest land cover was similar to 1974-75, and a high degree of fragmentation remained. 1992 maps showed most of the basin covered in young forest, with small patches of mature forest fragments throughout. The historic trends in upland forest cover show the dramatic reforestation that occurred in the latter half of the 1900s, as forest lands were allowed to grow back from the devasting fires. This growth potential in the uplands is encouraging for the development of timber harvest management plans that seek to balance ecological and economic interests.

Lowland forest cover maps were created only for the 1974-75 and 1986 time periods from available GIS data, and thus do not provide significant historical information (Figure 6-5-3). A 20 percent coverage of the lowlands by forest in 1857 was assumed based on estimated conversion of lands to pasture at that time. The lowland estimates provide a reasonable landscape-scale view of forest cover during those periods. Unlike the uplands, it is evident that lowland forest cover has not had the opportunity to increase due to established

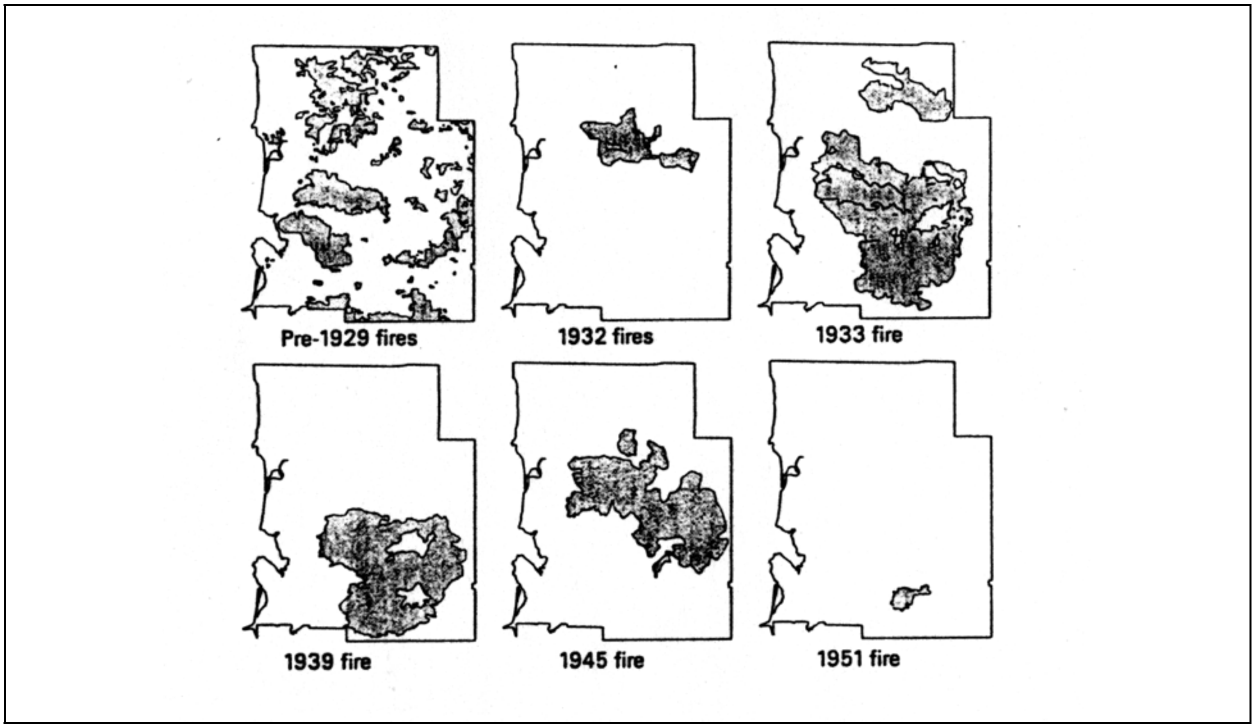

Figure 6-5-2. Historic Burn Areas in Tillamook County Source: Chen, 1997

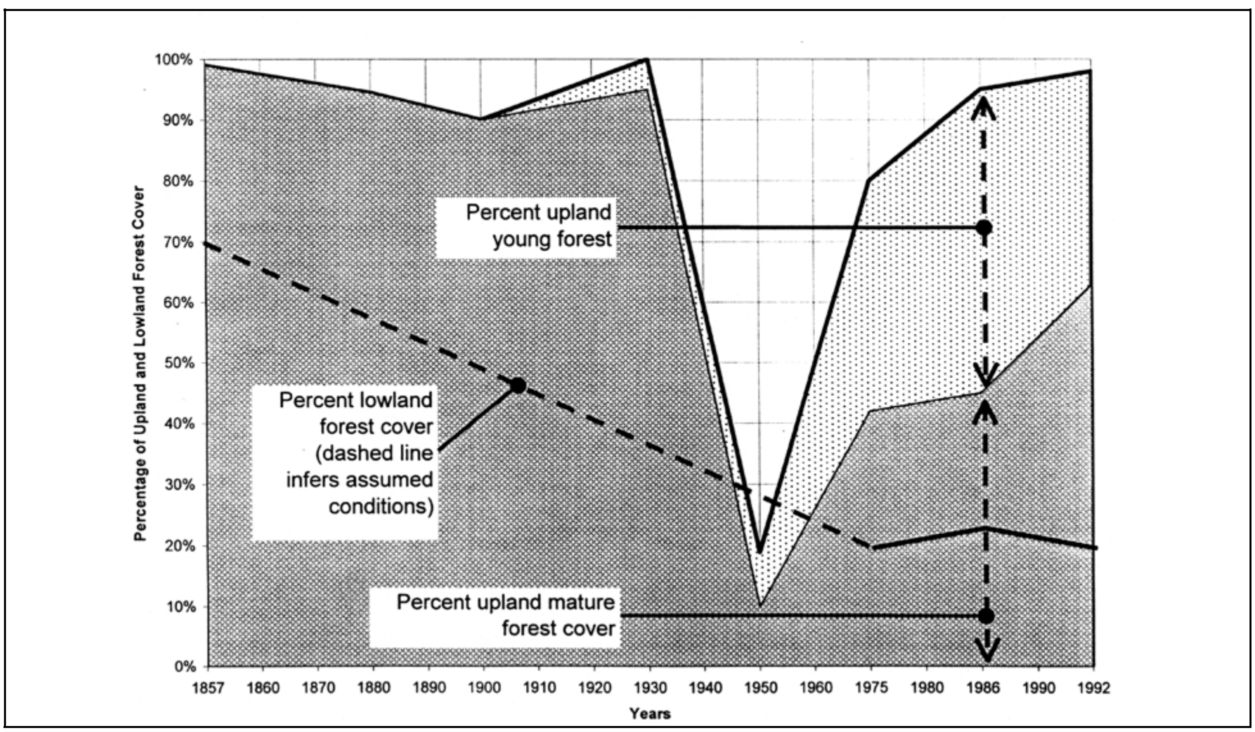

Figure 6-5-3. Historic Trends in Tillamook Upland and Lowland Forest Cover

agricultural and urban land uses. Restoration and integration of riparian corridors along the lowland rivers and sloughs would add to ecological diversity in the lowlands and create fish & wildlife habitats.

In many cases, GIS data layers used in this assessment were not compatible, did not have the same resolution, or did not have the same accuracy and could not be used to analyze terrestrial ecology at less than a landscape scale. In some cases, it could not be determined if these differences occurred within a single data layer. These are typical limitations to GIS-based ecological analyses. Since the Tillamook project is potentially a pilot for such studies throughout the region, protocols should be based on methods feasible in areas where GIS data are not available.

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6.6 River Morphology

6.6.1 River Channel Planform Changes

■ Objectives

Rivers display a dynamic pattern of meandering over time. A comparison of river channel planforms — channel width and alignment — over time can provide a record of past changes in the channel and indicate future meandering and bank erosion tendencies. The focus of this assessment was the lowland valleys of the Tillamook Bay basin, because planform changes are more discernable in these low-relief, unconstrained areas, and because bank erosion concerns are more predominant here. The objectives of the assessment were to evaluate: 1) the change in river channel widths over time; 2) the trends in channel migration; and, 3) the trends in channel stability.

■ Methods

Current USGS digital 1:24,000 topographic maps of the Tillamook Bay lowland valleys were used as base maps for the comparison. These maps were developed from aerial photographs taken between 1975 and 1980. The first topographic maps for the area were published in 1942 by the U.S. Army War Department at a scale of 1:62,500. These early maps were developed from aerial photographs taken in 1939. The 1939 maps were enlarged to the same scale as the current maps and compared together over a light table. The planforms of the 1939 rivers were transferred to the current maps by tracing. There may be significant errors associated with a comparison of different editions of USGS maps because of inaccuracies or inconsistencies in the horizontal plane coordinates. Errors were minimized by aligning road intersections, benchmark locations and other spatial features common to the two map periods and comparing discrete reaches of river only in the immediate vicinity of the aligned cultural features. A similar exercise was done with the 1955 quadrangle map series, with river planforms transferred to the current map base. Figure 6-6-1 shows a close-up of the Wilson River combining planforms from the three time periods. Due to the error involved in this type of a comparison, the resulting maps of river planform change are not necessarily accurate representations of river location, but they provide a general indication of river channel changes over time.

■ Discussion

The river channels in the Tillamook Bay lowlands display noticeable patterns of both meandering and stability. Meandering is most apparent in the head of the lowlands, where the rivers rapidly change gradient from the uplands. The upper reaches of the Trask and Wilson Rivers display progressive downstream channel migration over the time periods assessed. These river reaches generally coincide with reaches where riverbank soils are prone to erosion. Many stable reaches of river are apparent further downstream in the lowlands. Stability may be an indication of resistant geology or soils, the use of revetment or, conversely, of shallower river channel conditions where flood flows are not constrained to the channel, but overflow onto the floodplain before excessive flow velocities and bank erosion occur.

The actively meandering reaches of the rivers should be managed in a way that conserves and protects this natural function of the river. Meandering dissipates energy in flowing water and regulates the movement of sediment through the river system. The aerial photograph of the Wilson River after the November 1998 flood (Figure 6-6-2) shows sediment deposition on floodplain lands and patterns of remnant channels and swales on the floodplain. This complexity of changing channel, bank and floodplain conditions creates aquatic habitat for salmon and other species.

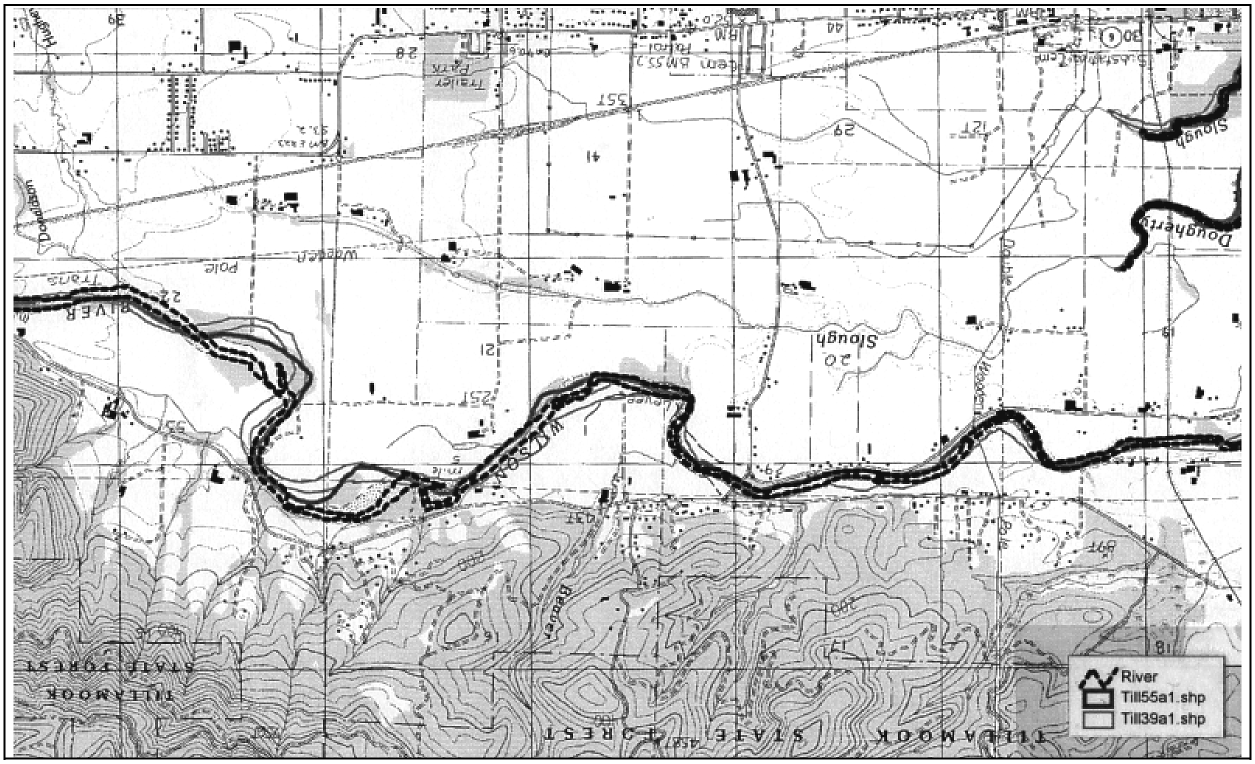


Figure 6-6-1. Detail of Wilson River Historic Planform Comparison Mapping

Figure 6-6-2. Aerial Oblique Photograph of 1998 Wilson River Flooding

6.6.2 Lowland Riverbank Stability and Erosion Assessment

▪ Objectives

The erosion of riverbanks is a natural process that contributes to the progression of river meandering across a lowland valley. The erosion process can be accentuated by disturbances to the bank and by flooding. The stability of riverbanks is an issue where property ownership and land use interests seek long-term use of the land. These interests are often protected by physically covering the riverbank with rock, or by other methods. These protection efforts are typically done on an individual property-by-property basis. Although bank protection may provide a level of protection to the property of interest, it may have unintended consequences and impacts upstream or downstream along the river system. The objective of this assessment was to evaluate the stability of the natural river banks along the lowland river reaches to provide a comprehensive look at the relative stability of river banks for the entire lowland system.

▪ Methods

A general indication of riverbank stability was established by adopting methods described in the Stream Restoration Handbook (Federal Interagency Stream Restoration Working Group, 1998). The soil survey for Tillamook was reviewed to identify the soil series along the banks of the lowland rivers. Soil interpretation records were obtained from the NRCS for these soils (Jasper, 1999). The soils records provide soils data for several depth classes. The surface depth class was generally not used in the assessment, in favor of soils associated with deeper classes that would be more susceptible to erosion from river flows. The soils series were grouped into soil types under the Unified Soil Classification System. The soils records provided data on moist bulk density in units of grams per cubic centimeter (gcc), which were converted to pounds per cubic foot (pcf) for a moist bulk unit weight [g]. The shear strength of the soils was estimated, assuming minimum values of cohesion and internal friction (U.S. Bureau of Reclamation, 1987). The Unified soil types were used to estimate minimum cohesion values [c] in pounds per square foot (psf). Referencing average engineering properties of compacted soils, a minimum friction angle [f] for each soil type was estimated, assuming unsaturated soil conditions.

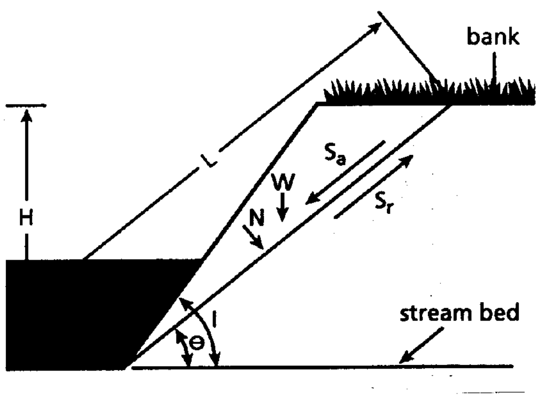
A stability number [N_s] was calculated for each soil type and for a range of bank angles [I] from 40 to 90 degrees using the relationship Ns = (4 sin I cos f)/(1-cos(I-f)). A critical bank height [H_c] was then calculated as a function of the geometry of the river bank, the soil properties and soil moisture conditions (Figure 6-6-3), where $H_c = N_s$ (c/g). Critical bank heights were estimated assuming "worst case" conditions, involving saturated banks and a rapid decline in river stage where the shear strength goes to zero, and unsaturated conditions. Accordingly, the process was repeated using a friction angle of zero to estimated stability under saturated soil conditions.

The resulting bank stability charts (Figures 6-6-4 through 6-6-7) show relationships between the critical bank height and the bank angle for the major lowland soil series. The upper line on the charts refers to critical bank heights for unsaturated conditions. Bank angles and heights above this line may present "unstable" conditions. The lower line represents critical bank heights for saturated conditions. Bank geometry conditions below this line may present "stable" conditions. Bank geometry conditions between the two lines may present "at risk" conditions for bank stability.

▪ Discussion

A saturated 45 degree bank angle was assumed typical of riverbank slopes during flood conditions in the lowlands and was used to perform a comparison of the relative stability of the lowland riverbanks. The riverbanks with soils having H_c values rated as unstable or at risk were designated as unstable and plotted on a map. Figure 6-6-8 provides a sample of the resulting unstable riverbanks for the Wilson and Trask Rivers.

The unstable riverbank reaches generally coincide with the upper reaches of the lowland rivers. These reaches have experienced significant meandering, as observed from the river channel planform change assessment. These reaches of the rivers should be managed by setting back infrastructure and allowing meandering and bank erosion to occur.



Explanation

H = bank height
L = failure plane length
c = cohesion
Φ = friction angle
γ = bulk unit weight
W = weight of failure block
(c, Φ, γ, W: soil properties)
I = bank angle
S_a = $W\sin\theta$ (driving force)
S_r = $cL + N\tan\Phi$ (resisting force)
N = $W\cos\theta$
θ = $(0.5I = 0.5\Phi)$ (failure plane angle)

for the critical case $S_a = S_r$ and:

$$H_c = \frac{4c \sin I \cos\Phi}{\gamma\,(1 - \cos[I - \Phi])}$$

Figure 6-6-3. Forces Acting on a Channel Bank Assuming there is Zero Pore-Water Pressure
Bank stability analyses relate strength of bank materials to bank height and angles, and to moisture conditions.

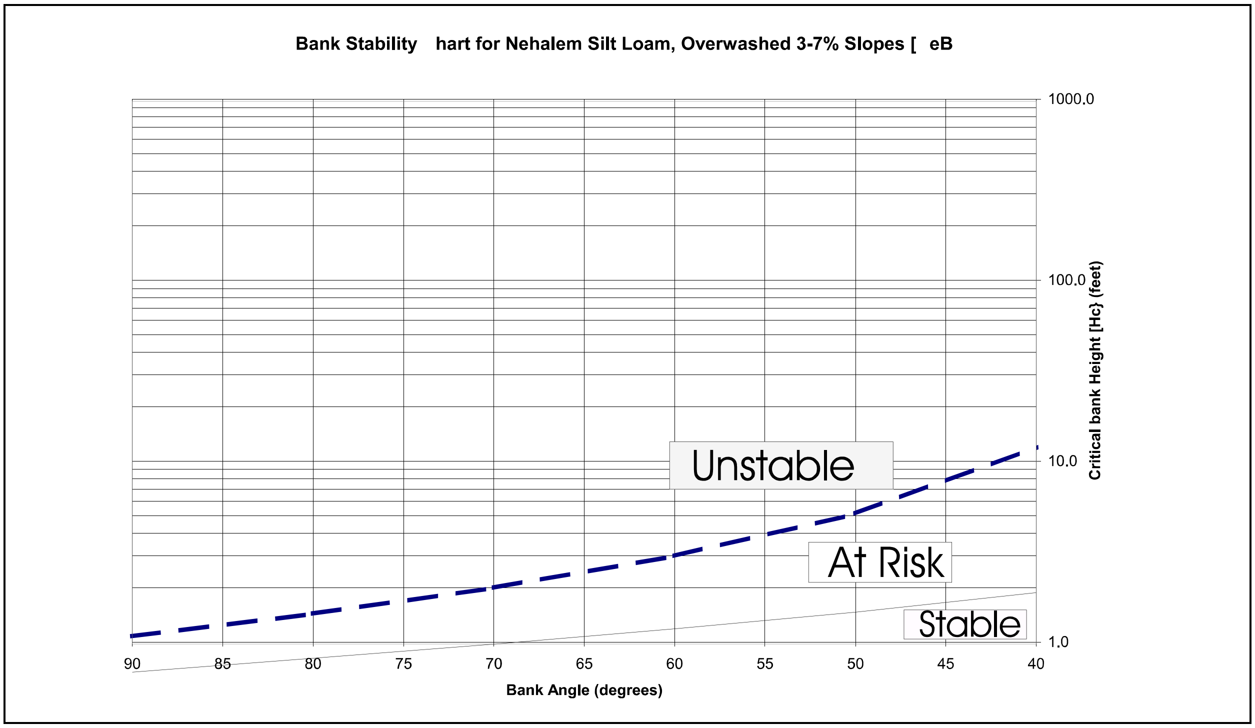


Figure 6-6-4. Bank Stability Chart for Nehalem Silt Loam, Overwashed 3-7% Slopes [NeB]

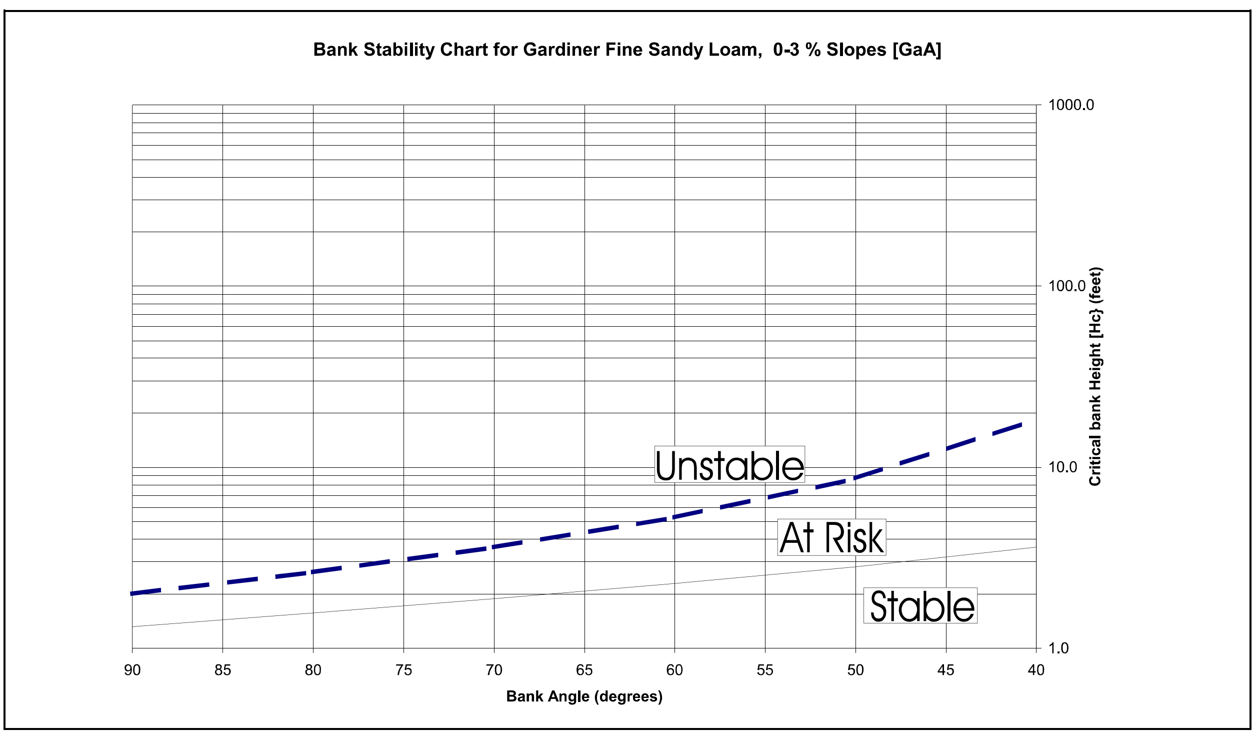


Figure 6-6-5. Bank Stability Chart for Gardiner Fine Sandy Loam, 0-3% Slopes [GaA]

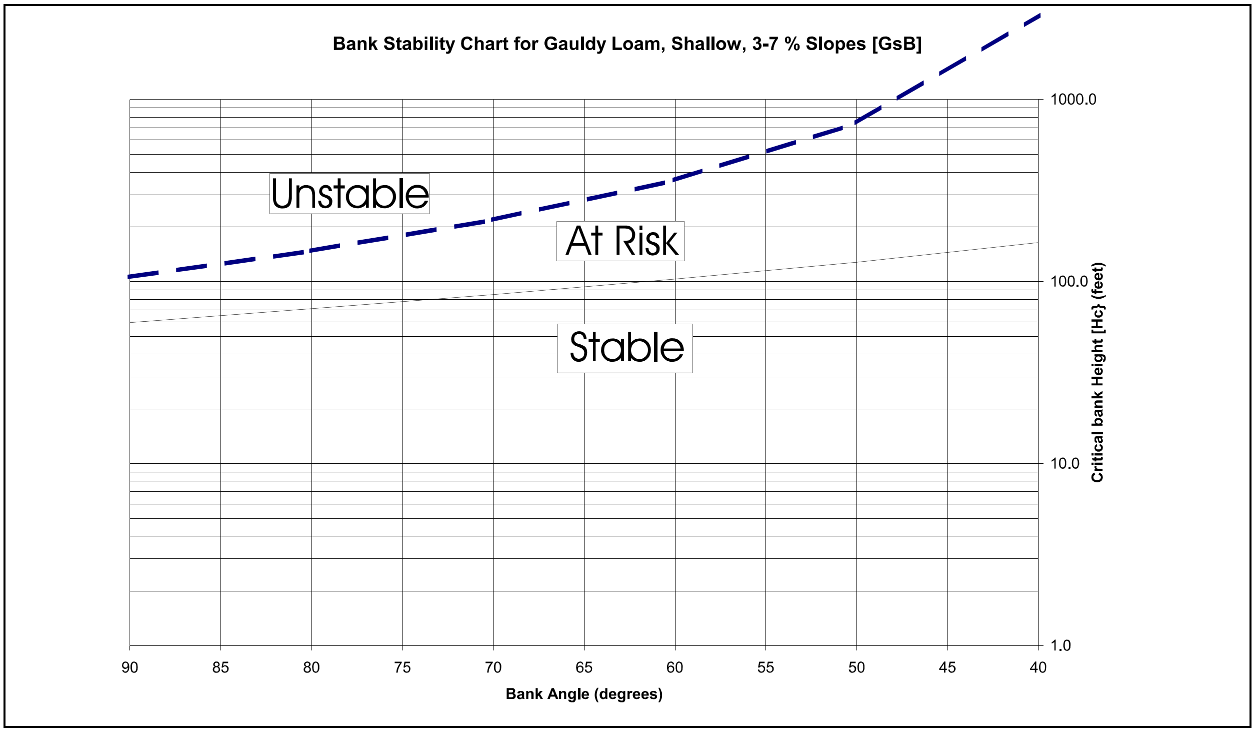


Figure 6-6-6. Bank Stability Chart for Gaudy Loam, Shallow, 3-7% [GsB]

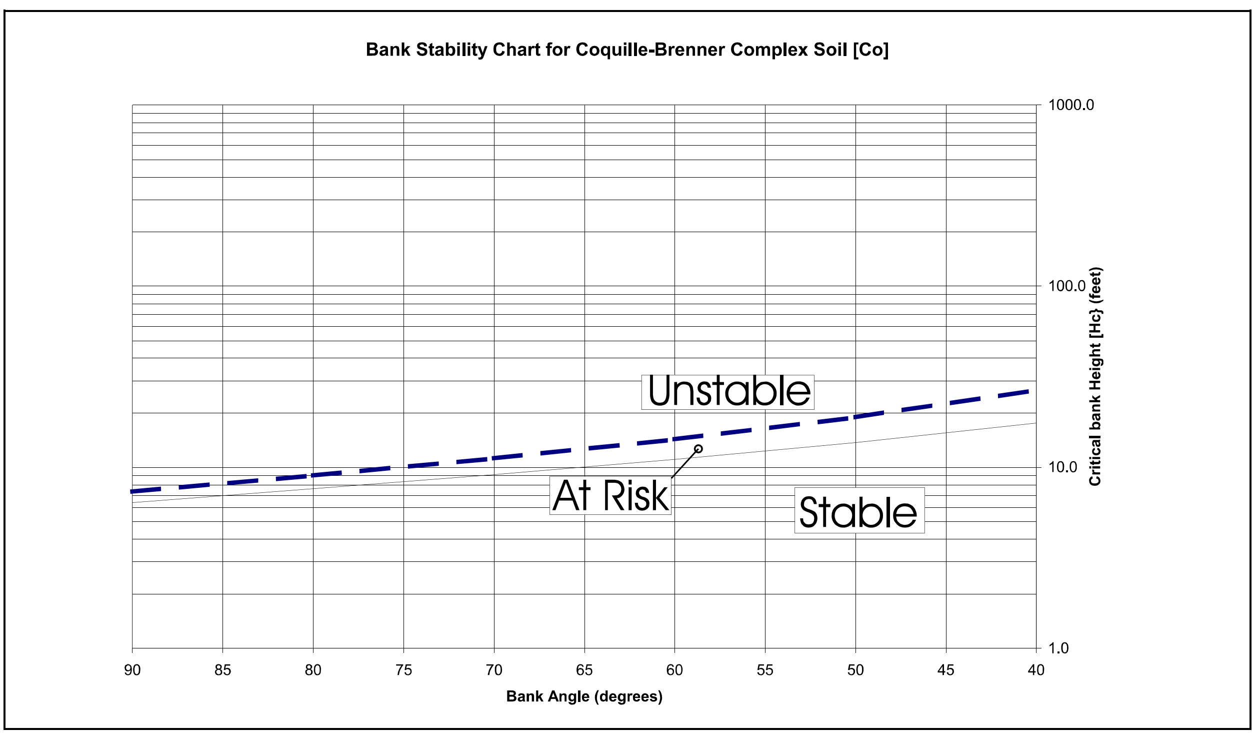


Figure 6-6-7. Bank Stability Chart for Coquille-Brenner Complex Soil [Co]

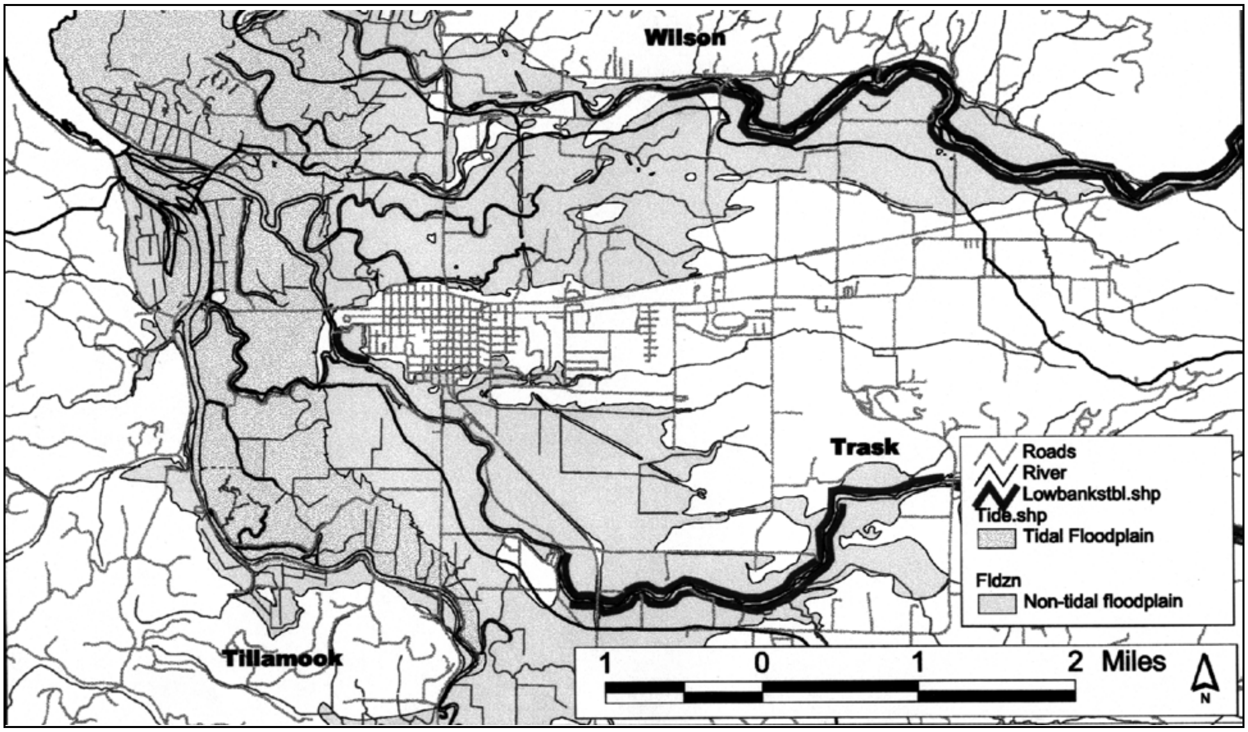


Figure 6-6-8. Unstable Riverbanks in the Tillamook Lowlands

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6.7 Salmon Habitat and Distribution

6.7.1 Salmonids in the Tillamook Bay Basin

■ Objectives

The objective of this assessment was to develop an understanding of the life cycle characteristics of salmonid species native in the Tillamook Basin, their habitat requirements and population dynamics.

■ Methods

Six different species or races of Pacific salmon are native to Tillamook Bay and its watershed (Kostow et al. 1995). These include chum salmon, coho, spring and fall chinook, winter steelhead, and cutthroat trout. Because the life histories and habitat preferences of these species differ, their temporal and spatial distributions within the basin also vary (Figures 6-7-1 and 6-7-2). Information on the history of these species within the basin, including catch statistics, spawner counts and hatchery programs, have been compiled by Moore et al. (1995), Coulton et al. (1996), and TBNEP (1998a).

Brief summaries of patterns of salmon use of the Tillamook Bay basin, particularly the lowlands and estuary, were developed, to identify the importance of these areas to each species inhabiting the basin. The information was synthesized from sources listed above and from additional literature on these fish. Relationships between spatial distributions the salmon species within the basin were assessed using GIS data available from the TBNEP. Pertinent GIS layers included CHUM, COHO, CHINFALL, CHINSPRG, STEELHEAD, and TILAHIST.

■ Discussion

Chum Salmon. In north-coastal Oregon, chum salmon are rarely found very far inland (OSGC, 1961), preferring to spawn in the lower reaches of mainstem rivers or in small floodplain streams tributary to the lower rivers (TBNEP, 1998b). Chum are also known to spawn in the upper intertidal reaches of rivers, streams, and sloughs. They have the shortest period of freshwater residency of any salmon found in Oregon and move quickly to estuarine rearing areas after emergence. These areas include tidal creeks and sloughs that allow chum fry access to key feeding areas in estuarine marshes. Studies in other estuaries have shown that juvenile chum salmon spend up to about a month in estuarine environments before moving toward the open ocean (Simenstad and Salo, 1982). Of the salmon in Tillamook Bay, chum are those most closely associated with the lowlands, which account for about 65% of their current geographic distribution upstream of the estuary (Figure 6-7-3).

Coho Salmon. With their preference for slow-flowing habitats, off-channel areas, and the cover provided by woody debris, coho may be found in low to moderate gradient streams within all but the smallest Tillamook Bay watersheds (Figure 6-7-4). Juveniles of the species frequently spend at least a portion of their one-year stay in freshwater in side-channels, beaver ponds, lowland sloughs or varied floodplain habitats. Under natural conditions, coho use of aquatic habitats in the Tillamook Bay lowlands would have been both extensive and intensive. In fact, the productivity of sub-populations of coho that spawn in upper portions of the basin may have been substantially enhanced by their ability to overwinter as juveniles in off-channel habitats in the Tillamook Bay lowlands. At present, lowland channels are thought to account for about 25% of the geographic distribution of coho within the stream network draining into the bay.

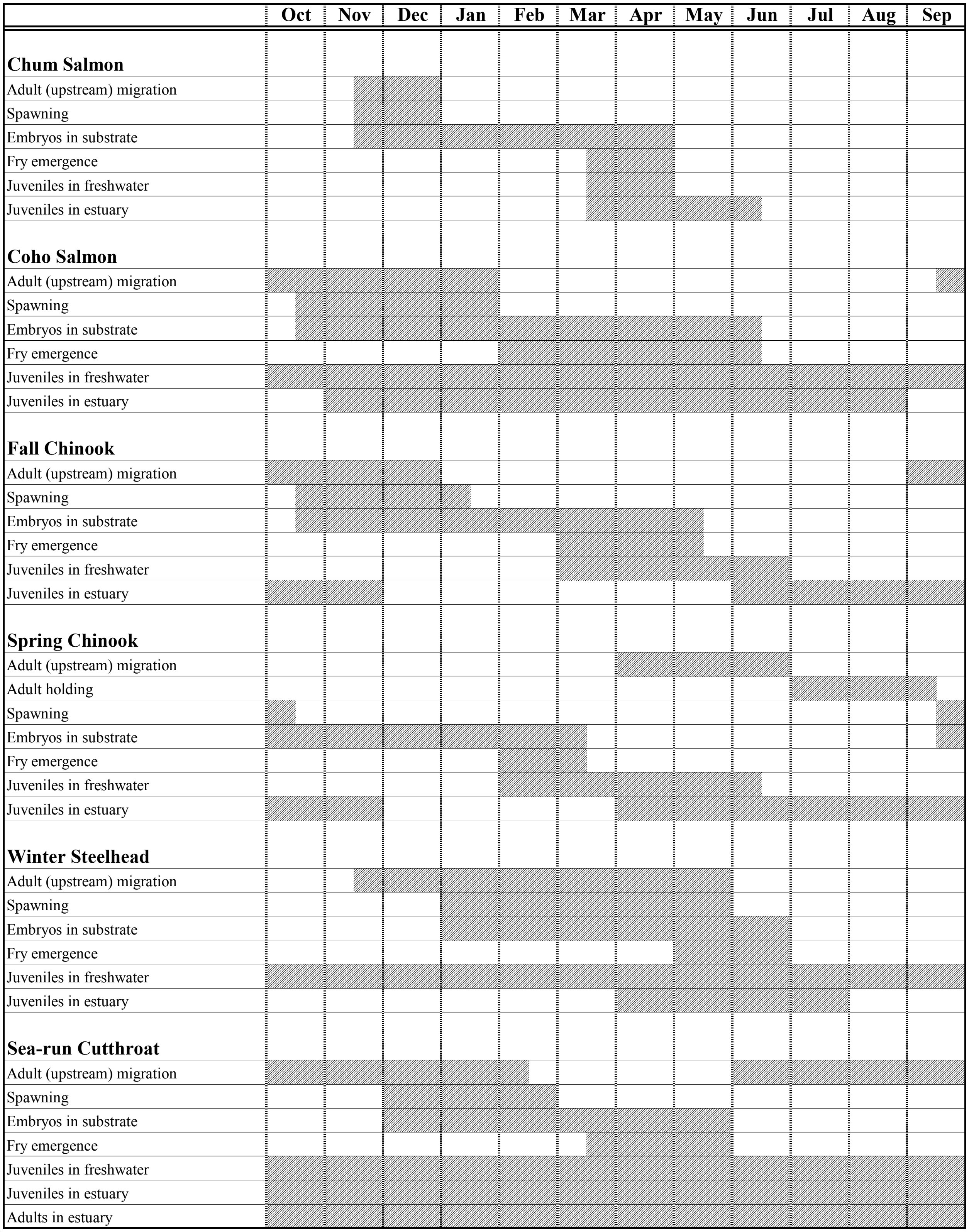

Figure 6-7-1. Seasonal Patterns in the Life Cycles of Tillamook Bay's Anadromous Salmonids

Figure 6-7-2. Historic Spawning and Rearing Areas for Salmon and Trout in Tillamook Bay's Uplands, Lowlands, and Estuary

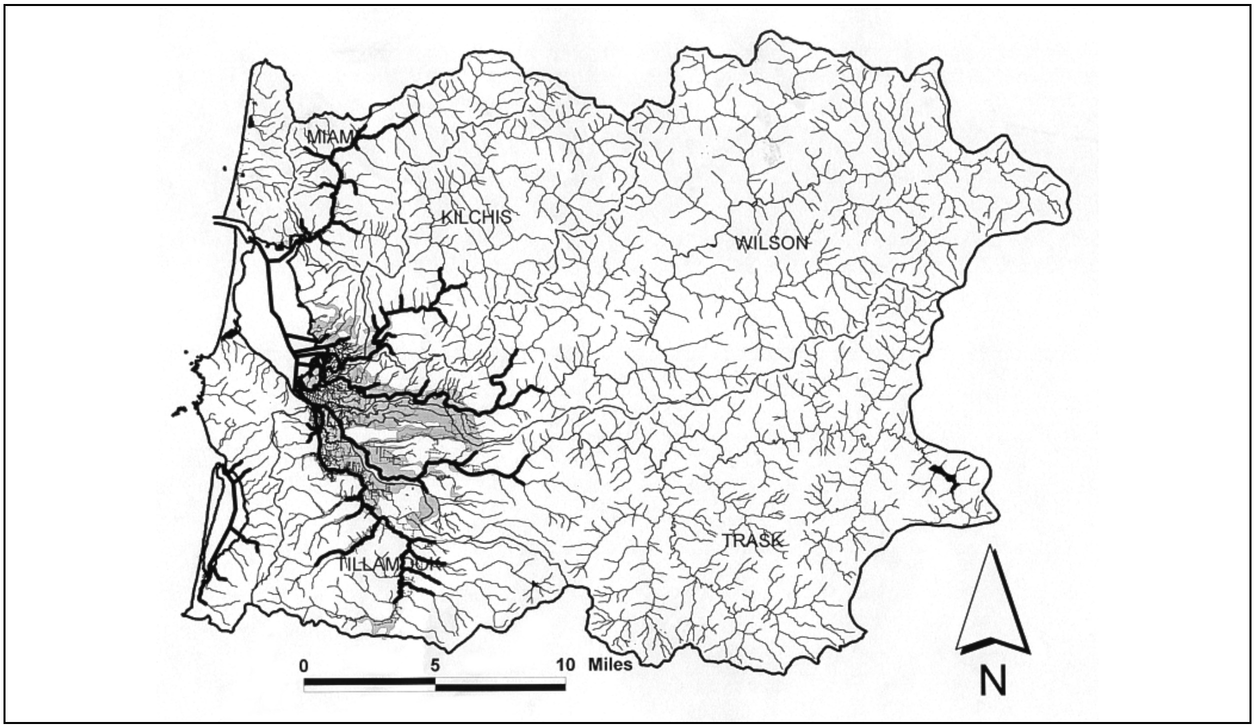

Figure 6-7-3. Chum Salmon

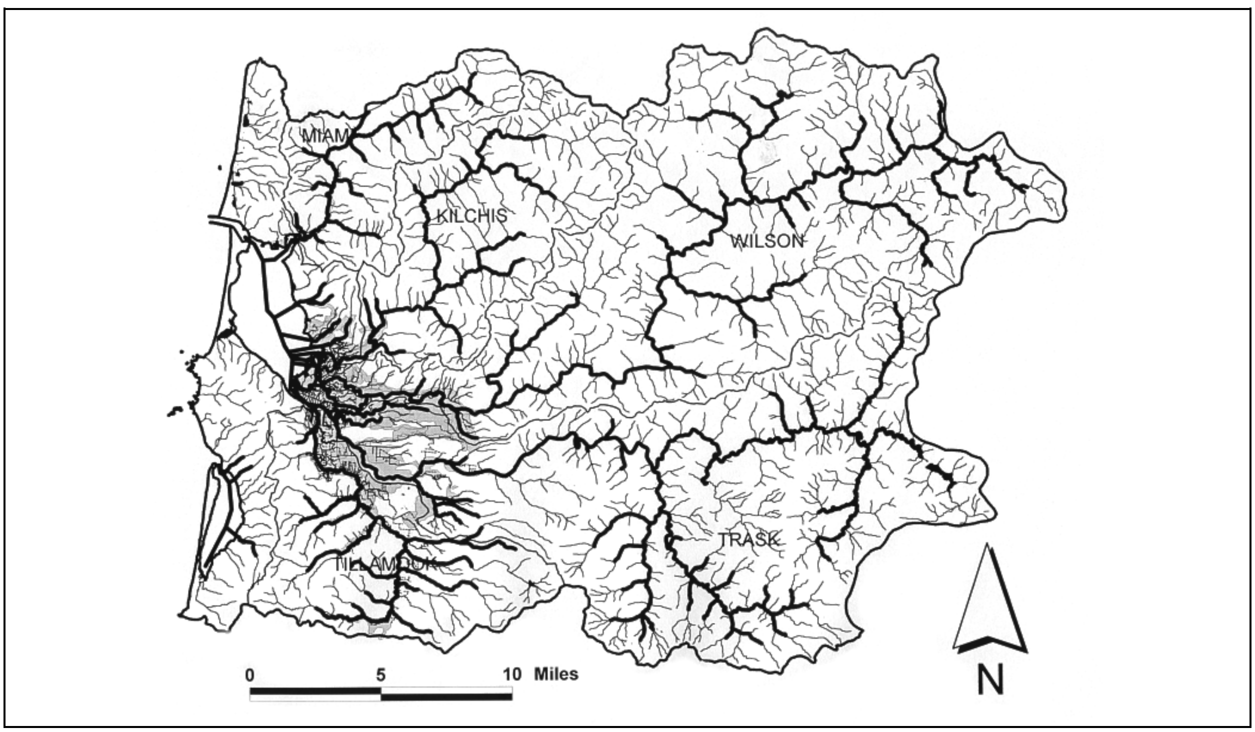

Figure 6-7-4. Coho Salmon

Spring Chinook. Spring chinook are native to the Trask, Wilson, and Kilchis river systems (Nicholas and Hankin 1988), but their distributions within these watersheds are generally restricted to mainstem channels and a couple of the largest tributaries (Figure 6-7-5). Lowland channels account for approximately 35% of the distribution of this species within the basin. Adult spring chinook migrate up the three rivers toward their upland spawning areas during the spring or early summer, hold during summer in pools that will be inaccessible to fall chinook until water levels rise after late fall rains, and spawn near their holding pools during the early fall. After emerging from the gravel during mid- to late winter, most juvenile spring chinook spend up to several months rearing in freshwater followed by up to six additional months in the estuary. Nicholas and Hankin (1988) note that all of the tidal reaches of Tillamook Bay have the potential to provide important estuarine rearing habitat for juvenile chinook.

Fall Chinook. Fall chinook are native to all five major rivers in the Tillamook Bay basin and differ from spring chinook in that they have a later upstream run (fall), a later spawning period, a wider selection of spawning sites due to differing streamflow conditions, and a later period of fry emergence (late winter or early spring). About 30% of the freshwater channels now used by these fish are found in the basin's lowlands (Figure 6-7-6). Historic dependence on these streams may have been greater if the geographic range of fall chinook has expanded in response to the simplification and widening of upland channels. Along with spring chinook, this race of salmon is thought to spend a period of time rearing in the estuary second only to sea-run cutthroat trout. Sub-yearling fish are found throughout the bay at certain times of the year.

Winter Steelhead. Winter steelhead are widely distributed throughout the Tillamook Bay basin and would have been similarly distributed prior to development (Figure 6-7-7). Lowland channels appear to account for about 20% of their freshwater distribution within the basin, a smaller percentage than for all of the other salmonids except cutthroat trout. Winter steelhead migrate upstream toward freshwater spawning areas from late fall through early spring, spawn in a diversity of stream channels during winter and spring, and emerge from spawning gravels as fry in late spring. Juveniles spend from one to three years rearing in freshwater, generally preferring tributary streams and areas with complex cover, before making a springtime migration to the estuary as smolts. These smolts move quickly through the estuary and out to sea.

Sea-Run Cutthroat Trout. Cutthroat trout are the most widely distributed salmonids in the Tillamook Bay basin. They exhibit both migratory and non-migratory life histories, and are typically the only salmonids found in the basin's steep headwater streams. Mature sea-run cutthroat trout migrate upstream toward freshwater spawning areas during summer and fall, then spawn in small first- and second-order streams in winter. Sea-run cutthroat fry emerge from spawning gravels in late winter or spring, then rear in small freshwater streams for two to four years before making a springtime migration toward the ocean as smolts. Under historical conditions, substantial numbers of these fish would have reared in small streams within the Tillamook Bay lowlands. Both juveniles and adults of the species commonly rear for extended periods in estuaries.

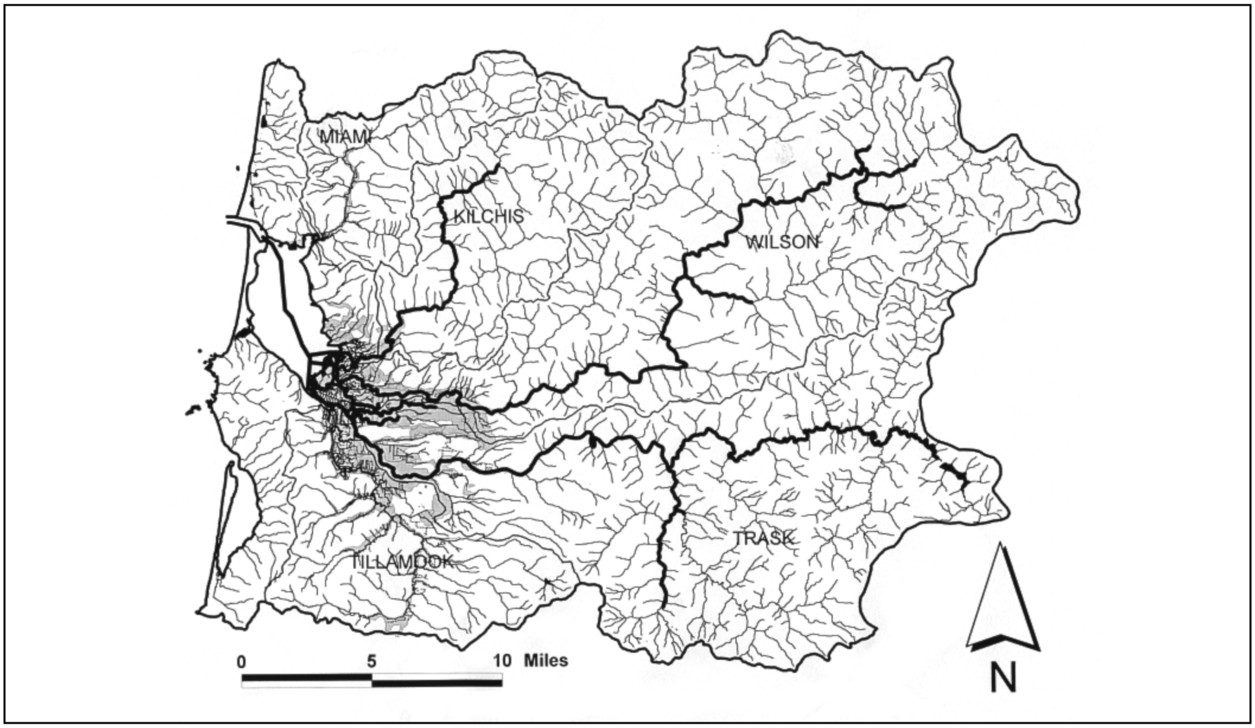

Figure 6-7-5. Spring Chinook

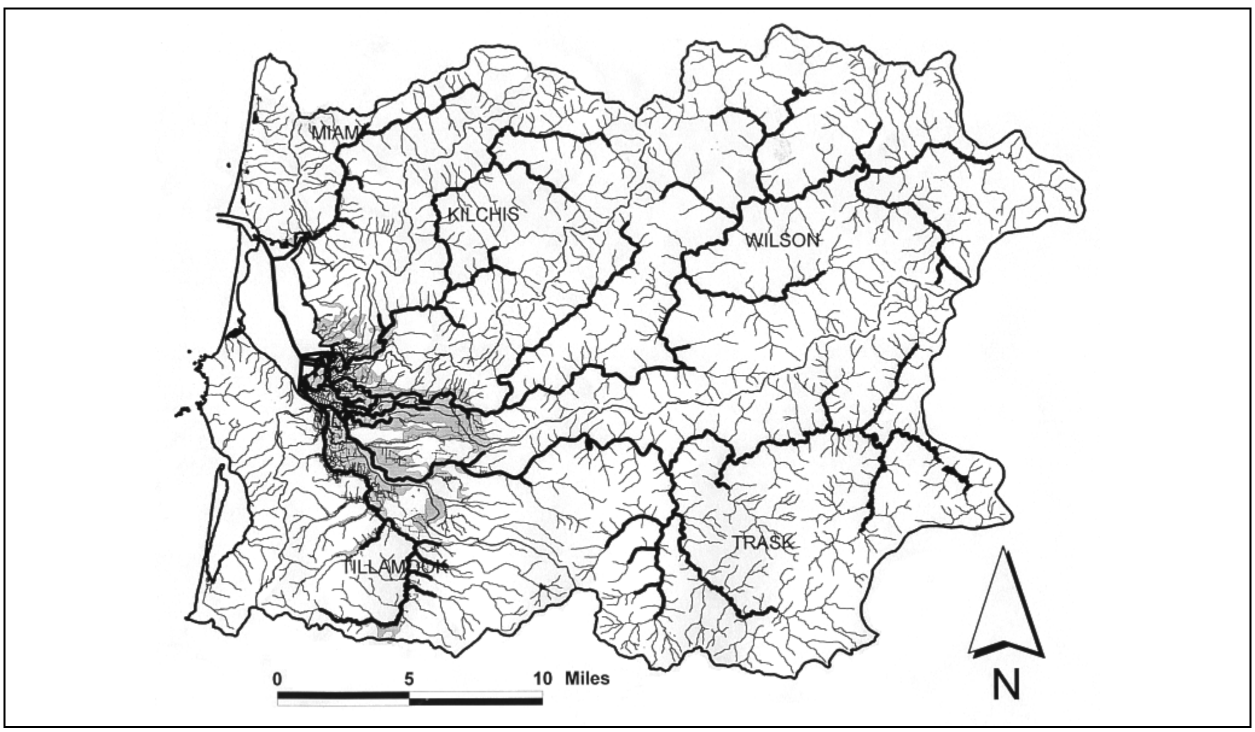

Figure 6-7-6. Fall Chinook

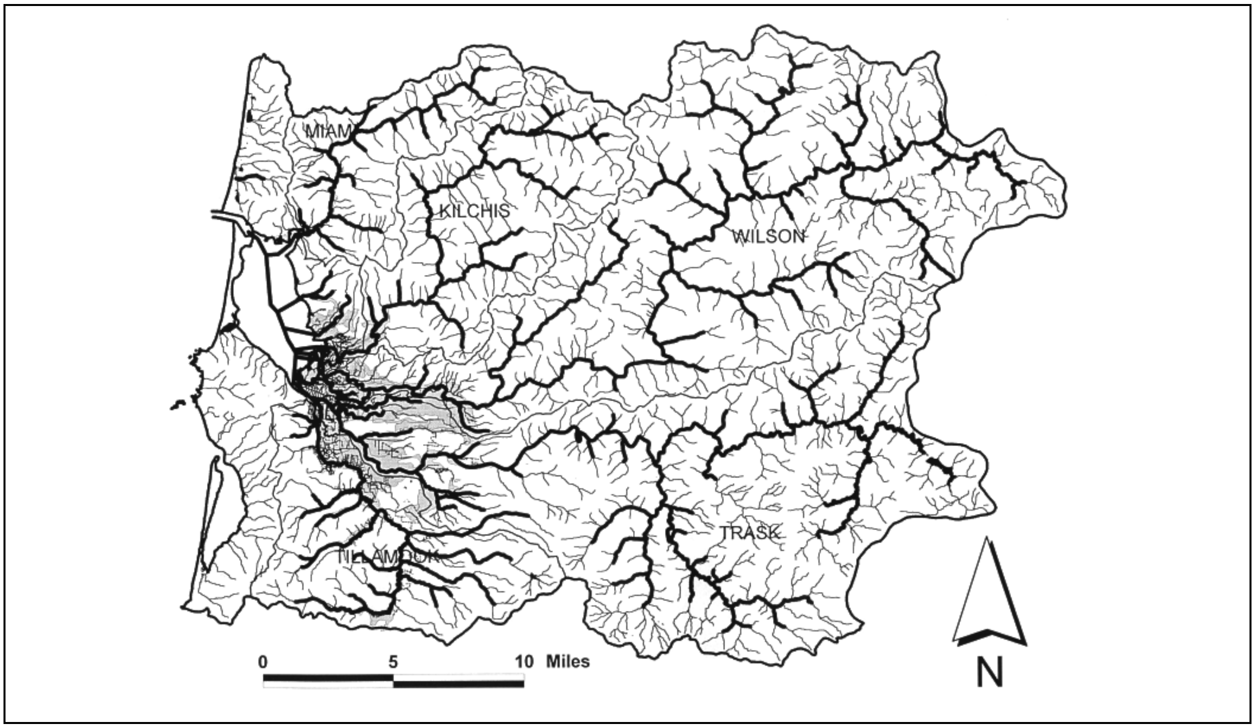

Figure 6-7-7. Winter Steelhead

6.7.2 Historic Salmon Abundance

■ **Objectives**

The objective of this assessment was to develop an understanding of the historic salmon production on the Oregon Coast and how production in the Tillamook Bay Basin compared to other coastal basins.

■ **Methods**

We examined data that Cobb (1930) summarized on the annual pack of salmon at canneries that operated at the turn of the century on Tillamook Bay and within other coastal Oregon basins, then supplemented these data with information on historic gill net catches reported by Cleaver (1951) and Smith (1956). We then examined recent assessments of these data by Lichatowich and Nicholas (1991) and Huntington and Frissell (1997), and drew general conclusions about turn of the century salmon production in Tillamook Bay and how it compared to other coastal basins. Data on the historic abundance of salmon were scaled to drainage basin area, to provide a common basis upon which to compare historic salmon productivity among basins.

■ **Discussion**

Historic peaks in annual cannery packs of salmon suggest that at the turn of the century the Tillamook Bay basin was the most productive salmon producer in the Oregon Coast Range (Figure 6-7-8). Not only was the area highly productive for salmon, but it differed from other coastal river basins within the Coast Range in that the most abundant species was chum and not coho salmon. This historical dominance of chum salmon has been overlooked in most retrospective assessments of the Tillamook Bay ecosystem. Lichatowich and Nicholas (1991) suggest that at the turn of the century the Tillamook Bay basin produced coho salmon at a rate (about 310 adults/mi^2/yr) equal to or higher than most other basins in the Oregon Coast Range. Huntington and Frissell (1997) estimated that the basin's capacity to produce chum salmon (apparently more than 610 adults/mi^2/yr, double the number of coho) was far greater than that of other river basins in coastal Oregon. Aquatic habitats within the basin have also been quite productive for other anadromous salmonids. Available data suggest that the basin was at or near the upper end of the range of Oregon's coastal basins in productivity for chinook salmon and for winter steelhead, although both of these species were less abundant than chum and coho.

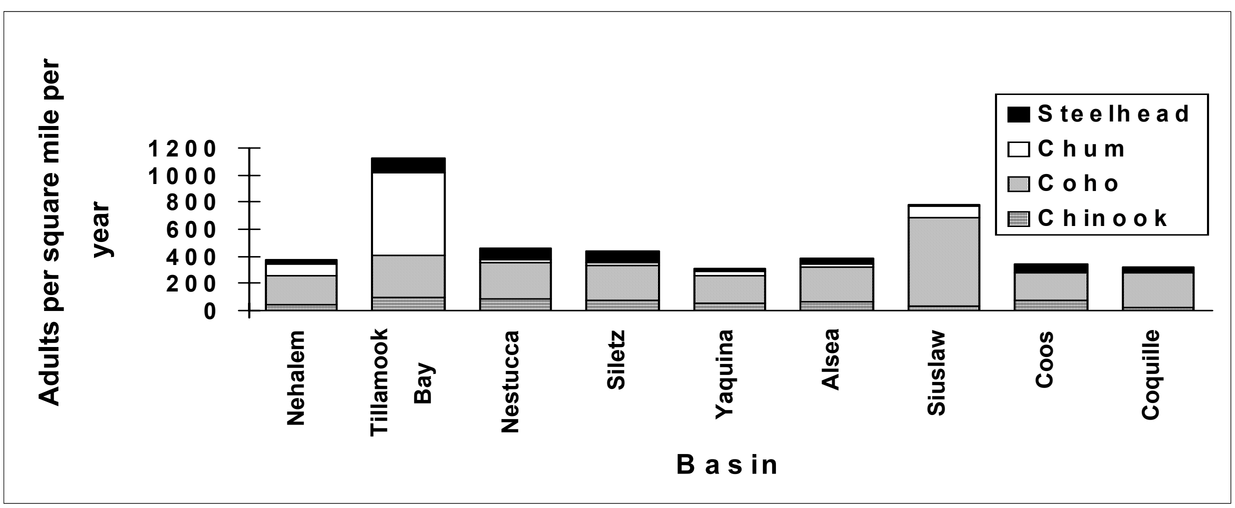

Figure 6-7-8. Catch-Based Estimates of Historic (c. 1900) Pacific Salmon Production in Nine Coastal Oregon River Basins. Adapted from Huntington and Frissell 1997.

6.7.3 Changes in Salmon Abundance

■ Objectives

The objective of this assessment was to document what is known about the recent and historic changes in salmon abundance.

The status of wild salmon populations within a basin is often considered an indicator of environmental health. Salmon declines in coastal Oregon and elsewhere in the Pacific Northwest have had many causes, including degradation and loss of freshwater and estuarine habitats, over-harvesting, and losses of genetic integrity due to the effects of hatchery practices and introductions of non-local stocks (Nehlsen et al., 1991; Kostow et al., 1995; OCSRI, 1997). These factors have often acted in concert, but the loss, degradation, and fragmentation of habitat have been those most frequently recognized as responsible for the declines (Nehlsen et al., 1991). Natural cycles in oceanic productivity also affect the abundance of Oregon's salmon (Bottom et al., 1986; Nickelson, 1986; Pearcy, 1992). These cycles complicate salmon management (Lichatowich, 1996), and make declining productivity of freshwater and estuarine habitats particularly troublesome for salmon during periods of low oceanic productivity (Lawson, 1995).

■ Methods

Recent status reviews of Tillamook Bay's multiple species of salmon were referenced. Then, available catch, escapement, harvest rate, and other records were used to reconstruct historic trends in abundance of the basin's wild chum and coho salmon. The reconstruction of abundance trends for these two species extended from 1923, the year the State of Oregon began keeping consistent records of the numbers of salmon caught by commercial fisheries, to the present. The focus is on chum and coho because of the quantitative dominance of these salmon in the historic ecosystem.

■ Discussion

The Current Status of Tillamook Bay Salmon. The status of various species of Tillamook Bay salmon has been reviewed by Nehlsen *et al.* (1991), Nickelson *et al.* (1992), ODFW (1995), Huntington *et al.* (1996), Huntington and Frissell (1997), multiple investigators from the National Marine Fisheries Service, and Ellis (1998). A general synthesis of these reviews, based largely on the assessment of Ellis (1998), is given in Table 6-7-1. Natural production of all species of salmon in the Tillamook Bay basin except fall chinook has declined during this century, with chum and coho salmon exhibiting the greatest reductions in numbers.

A full explanation of why Tillamook Bay's fall chinook are doing well is unavailable, but historic catch statistics suggest they became consistently more abundant than the basin's spring chinook after the mid-1930s. Gharrett and Hodges (1950) reported that they were doing better than most other fall chinook stocks on the Oregon Coast as far back as the late 1940s. Huntington and Frissell (1997) suggested that factors contributing to the currently robust status of the basin's fall chinook may include: colonization of tributaries inaccessible to them before stream channels became simplified; use of habitats least vulnerable to land use impacts or left vacant by declining salmon species; factors of ocean feeding locations, harvest patterns, and partial recovery of the Tillamook Burn.

TABLE 6-7-1. Current Status of Wild Anadromous Salmonids in the Tillamook Bay Basin, Oregon

Species/race	Status	Recent population trends[1]
Chum salmon	severely depressed (two or more orders of magnitude less than historic abundance)	declining
Coho salmon	severely depressed (two or more orders of magnitude less than historic abundance)	declining
Fall chinook	healthy (recent abundance has been similar to historic levels, suggesting robust populations)	stable or increasing
Spring chinook	depressed from historic levels, heavily influenced by hatcherty fish	possibly declining
Winter steelhead	depressed (perhaps one order of magnitude less than historic abundance), heavily influenced by hatchery fish	declining
Sea-run chutthroat trout	depressed	possibly declining

Patterns of Decline for Tillamook Bay Chum and Coho Salmon. The reconstruction of post-1923 declines in the abundance of Tillamook Bay chum and coho salmon are given in Figure 6-7-8, with changes in stock sizes and spawning escapements shown separately. Abundance of chum salmon appears to have been erratic but relatively high from the mid-1920s until the mid-1940s, when it began experiencing a steep decline from which it has not recovered. Oakley (1966) noted that similar, perhaps less precipitous declines were observed across large areas of the Pacific Northwest at about this same time, and suggested that a climate shift or oceanic factor was largely responsible. Deleterious lowland and watershed conditions that were widespread in the region but particularly severe in the Tillamook Bay basin have also played a role, affecting important spawning and early rearing areas. Chum abundance in the basin rose slightly after all commercial salmon fishing within Tillamook Bay ended in 1961, but began a second period of decline in the late 1970s that continues today. Despite their low abundance by historical standards, chum salmon are more abundant in the Tillamook Bay basin than elsewhere in Oregon. The basin represents the best opportunity for assuring the species' continued presence in the state.

Wild Tillamook Bay coho appear to have declined more slowly than the basin's chum salmon, although by the early 1940s their total numbers (i.e., stock size) had already fallen to less than half those estimated for the turn of the century (<130 adults/mi^2/yr versus about 310 adults/mi2/yr). The basin's production of wild coho declined in an erratic fashion between the late 1930s and late 1950s, then increased during the 1960s and early 1970s in response to highly favorable ocean conditions. Our estimates of this increased wild production (as seen in Figure 6-7-8) are inflated to an unknown degree by increases in natural spawning by stray hatchery fish. Much like the chum, coho have declined since the mid-1970s and are now no more than about 1% as abundant as they are estimated to have been at the turn of the century. ODFW (1995) and Nickelson and Lawson (1997) identified Tillamook Bay's coho populations as being among the most severely 'at-risk' of the many ESA-listed populations on the Oregon Coast. Declining habitat quality, periodic downturns in oceanic productivity, and harvest rates that have at times been extraordinarily high for coho salmon, have combined to severely depress the numbers of adult chum and coho salmon reaching spawning grounds within the Tillamook Bay basin since the late 1950s. Research by Cederholm *et al.* (1999) on the role of salmon in cycling marine nutrients back to watersheds suggests that low spawning escapements such as these may themselves have had deleterious effects on the basin's aquatic ecosystems.

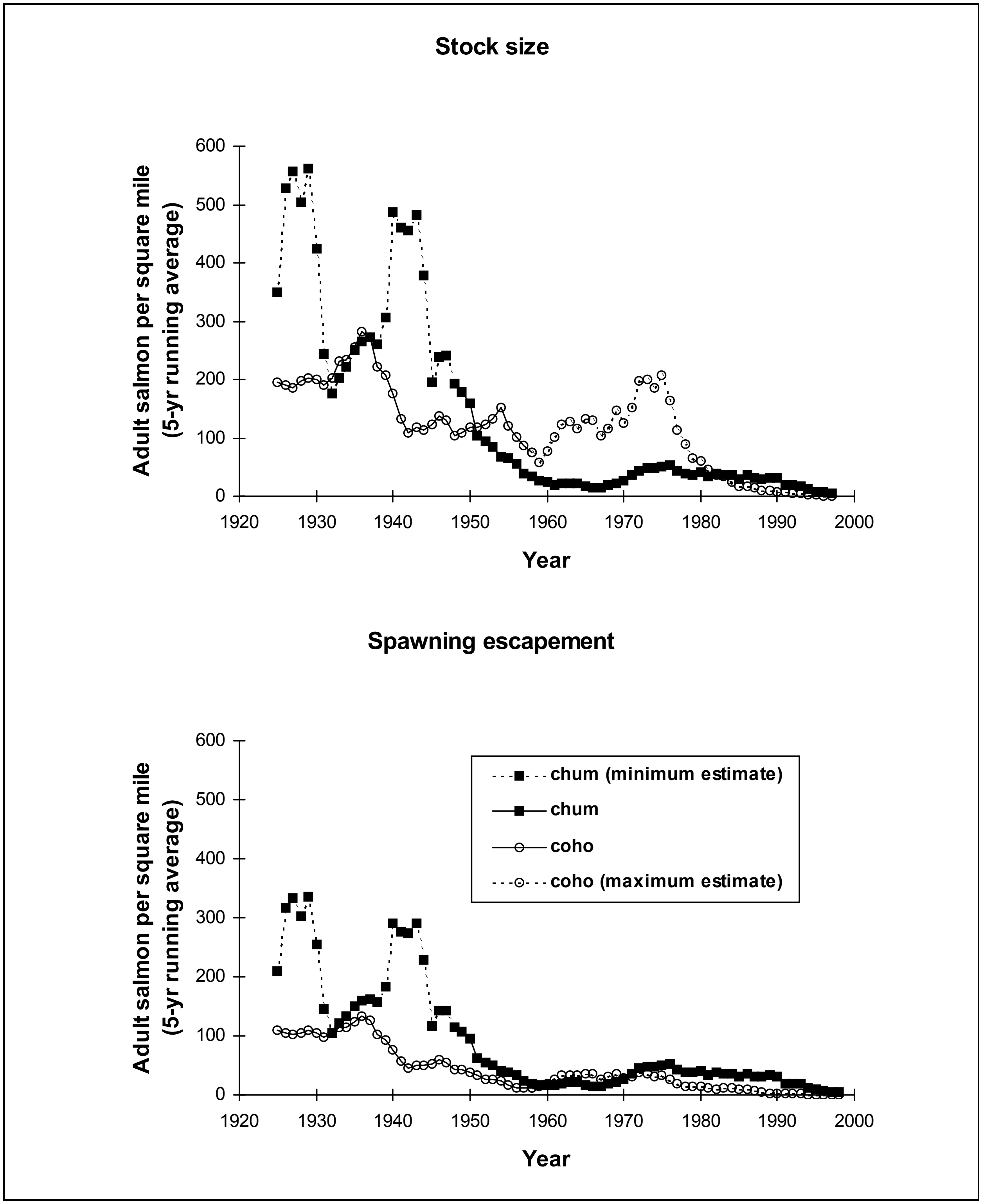

Figure 6-7-9. Estimated Declines in Stock Sizes (top) and Spawning Escapements (bottom) for Wild Tillamook Bay Chum and Coho Salmon, 1923-1999. (See Appendix 1 on the following page for more information.)

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6.8 Human Land Use and Flood Risk

Human land use is directly linked to flood risk and salmon habitat degradation. The economic benefits derived from human land uses are often the primary obstacles to making changes in the policies and practices of floodplain management. This section includes assessments of land ownership and use, stream crossings and diversions, water quality, dikes and levees, and flood damage claims and permits.

6.8.1 Floodplain Land Use and Development

▪ Objectives

The extent and type of flood hazards are a reflection of the characteristics of land use occurring within floodplain lands. The objective of the floodplain land use assessment was to characterize the types of human land uses occurring within the regulatory 100-year floodplain in the Tillamook Bay lowland valley areas. Land uses within the floodplain can be linked to flood damage claims and permits and to the policies and programs affecting floodplain development and flood risk mitigation. Understanding the distribution and quantity of land in various uses helps to define management strategies and to identify and prioritize courses of action.

▪ Methods

Current Tillamook Bay lowland land use GIS data was obtained from the TBNEP. These data were sorted into the following general land use categories: agriculture, farm buildings, rural residential, rural industrial, and urban. The coverage was then clipped to the extent of the FEMA Q3 100-year floodplain. A detail of the floodplain around Tillamook is mapped in Figure 6-8-1. The coverage provides a summary of the acreage of different land use types within the 100-year floodplain of the Tillamook Bay. The resulting land use acreages are presented in a pie chart (Figure 6-8-2).

▪ Discussion

As expected, agriculture is the predominant land use type within the lowland valley areas. Agriculture in the basin is primarily associated with Tillamook's dairy industry, so most of the agricultural land is used as pasture. Flood risk in this area is primarily livestock health and loss of access to grazing land. Strategies that facilitate post-flood drainage will provide great benefits in this area. This land use includes farm buildings, which represent the smallest land use acreage in the 100-year floodplain. Some of these areas correspond to confined animal feeding operations (CAFOs). These may pose a serious threat to human health and aquatic habitat when exposed to flood water.

There is some rural residential development in the basin. It is clustered along the roads and rivers and may indicate increased damage claim amounts following flood events. Rural industrial use in the basin is primarily gravel extraction and is also clustered along the rivers. Management of these uses should be considered and prioritized based on the intensity of the industrial use versus that of other land uses that cover a greater area of the floodplain.

Urban land use is the second most extensive use in the 100-year floodplain. A large portion of this use is along Highway 101 north of the city of Tillamook. Though the acreage in agricultural use within the 100-year floodplain is twice that of the acreage in urban use, the value per acre of urban land is substantially higher than that of pasture land. This is especially true in Oregon where land use planning confines urban development to urban growth areas. There is, therefore, an increased likelihood of higher damage claims in the urban areas, so efforts to reduce flood risk in urban areas will have a greater overall effect on reducing the total amount spent on damages. Conversely, the relatively small area and short length of stream channels inside urban areas may limit the benefit to salmon created through floodplain management efforts in urban settings. The longer contiguous reaches of river on agricultural lands presents greater opportunities from an aquatic habitat perspective.

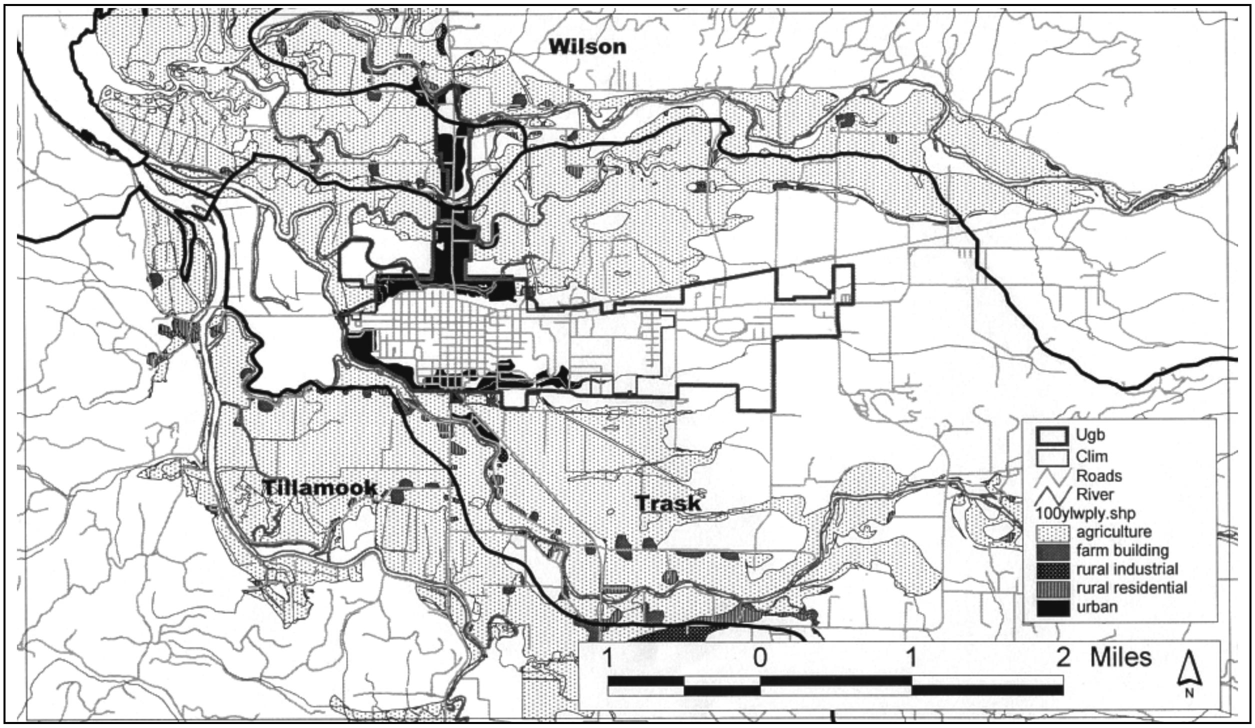

Figure 6-8-1. Generalized Land Use within the FEMA 100-Year Floodplain

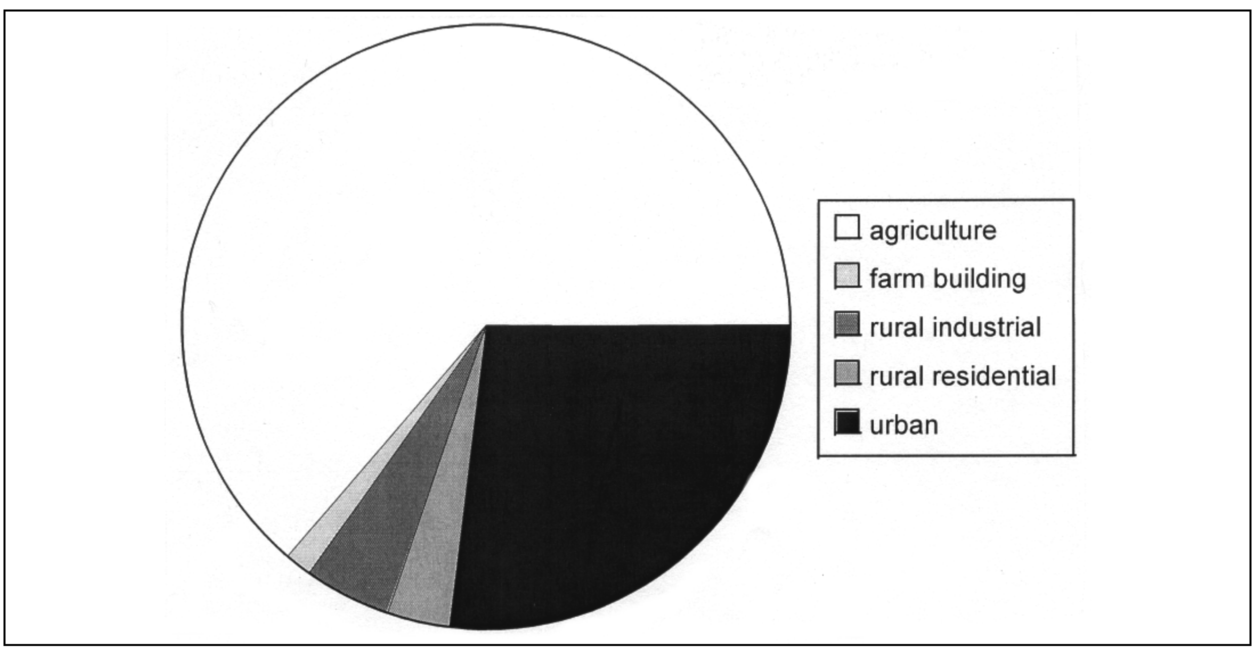

Figure 6-8-2. FEMA 100-Year Floodplain Land Use

6.8.2 Stream Crossings

■ Objectives

The linear characteristics of roads and railroads often result in stream crossings. Traditionally, the most economical method employed for conveying streamflow through a crossing was with the use of a culvert and an earth fill embankment. This technique often restricts the cross-sectional area of a stream and causes changes in flow velocity, leading to unnatural erosion and deposition patterns in the stream, locally and upstream and/or downstream. In many cases, a pool and drop will form downstream of the culvert because of these conditions, creating a barrier to salmon passage, or flow will be concentrated in the culvert and water velocities will be too high for salmon to swim against. Culverts also perform poorly in flood events and can be washed out at high flows, causing localized landslides, especially in steeper sloped upland areas. The objective of this assessment was to identify the location and distribution of stream crossings in the Tillamook Basin and lowlands and evaluate their importance in a river management strategy.

■ Methods

A GIS coverage of culvert locations in the Tillamook Basin was obtained from the TBNEP (Figure 6-8-3). The coverage was created by TBNEP for ODFW and maps all culverts in the Tillamook Basin that are assumed fish barriers. Additional culverts are known to exist within the basin uplands and are associated with state and private forestry roads. These data are being prepared by the Oregon Department of Forestry (ODF); however, they were not yet available during the course of this investigation. The basin mapping is enlarged to show culverts and tide gates in the Tillamook lowlands (Figure 6-8-4).

■ Discussion

Since culverts are primarily associated with roadways, the heaviest concentration of stream crossings is in the lowlands and the low elevation uplands (Figure 6-8-3). The Trask, Tillamook and Miami River subbasins have culverts distributed throughout their areas. The Kilchis subbasin has relatively fewer culverts in headwater areas, as does the middle portion of the Wilson subbasin. Salmon recovery efforts may be most viable in portions of the basin where these upland interventions in the river system are few, because natural processes may be relatively intact and salmon passage may be available for a wider range of seasonal streamflows. Where single ownership of large land parcels (and associated culverts) exists in upland sub-watersheds coordinated efforts to improve stream crossings may be more feasible than if multiple land owners are involved.

The dispersed locations of culverts and tide gates in the lowlands (Figure 6-8-4) represents a patchwork of flood control structures that modifies and complicates the natural flow of the tides and streamflows in the lowlands. Unforeseen circumstances, such as debris blockages after flood events, may create localized maintenance problems and lead to unintended consequences in the operation of the gates. Tide gated diversion structures or backwaters may also strand and kill fish that enter and cannot get out, and die as the side channels dry out (or get washed into fields). A system-wide effort to retrofit or remove these structures could reduce regional flood risk and restore large contiguous areas of habitat, but may be hindered by multiple ownership of the structures.

Culverts and tide gates are some of the more intrusive elements in a river system because they directly and significantly alter sediment and water flow patterns, leading to morphological changes and fish passage barriers. Since the physical effects of a culvert may impact large reaches of a river and upstream fish distributions, modification or removal of these structures should be prioritized to restore natural processes and fish access to restored river reaches.

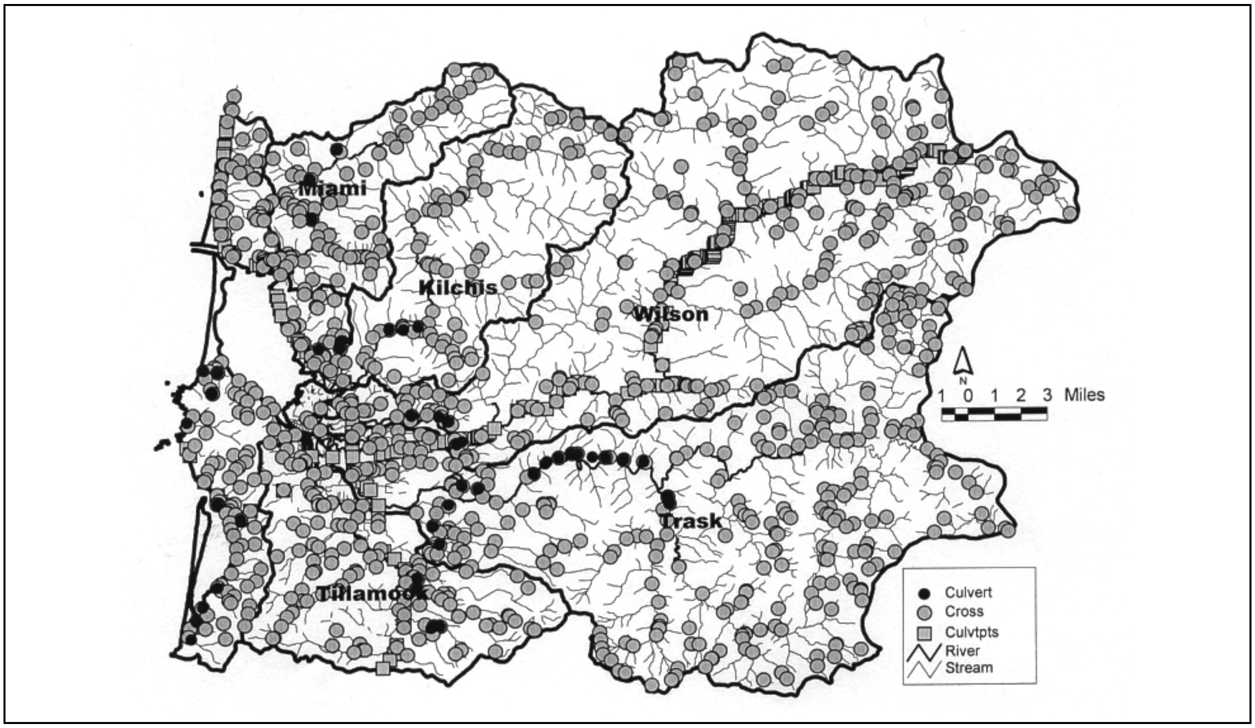

Figure 6-8-3. Basin Stream and River Crossings by Source

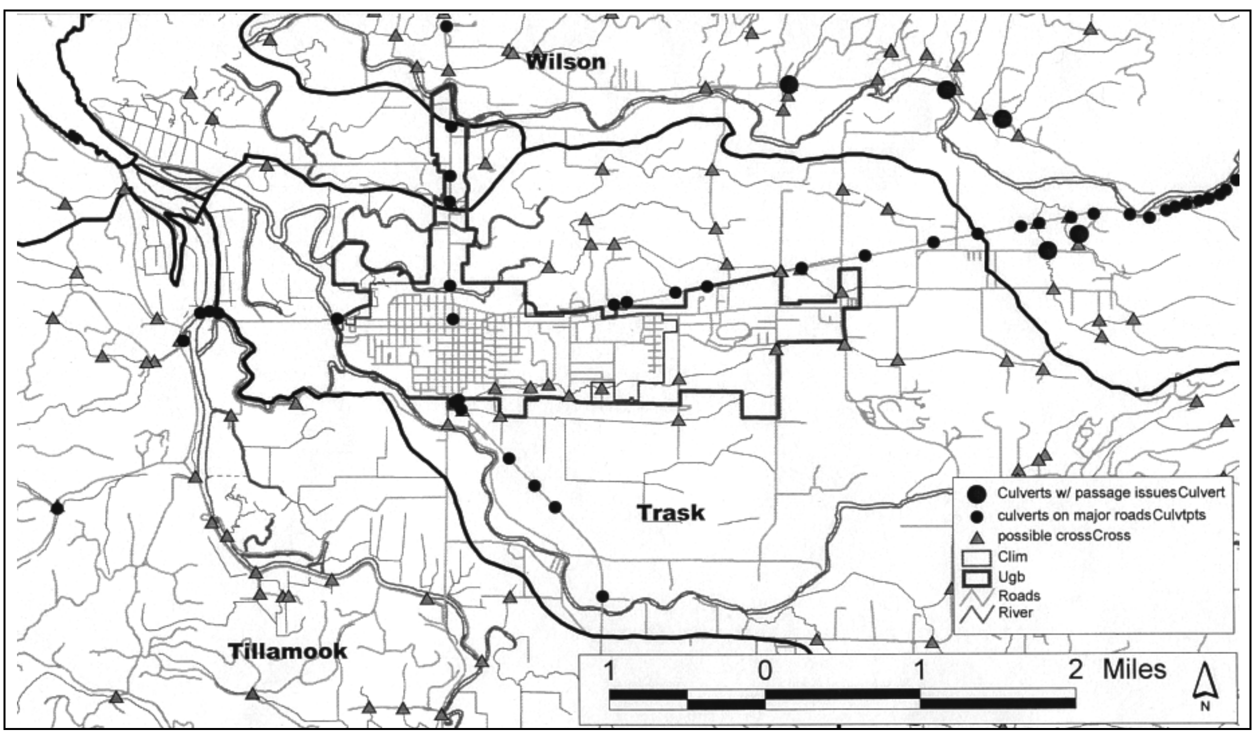

Figure 6-8-4. Tillamook Lowland Valley Stream and River Crossings

6.8.3 Dikes and Levees

■ Objectives

The construction of dikes and levees is associated with a number of impacts affecting both aquatic habitat and flood risk. The objective of this assessment was to better understand the impacts of levees and dikes in the Tillamook Bay Basin estuary. Levee locations, when combined with information on native vegetation and channel planform, will help to develop and prioritize management strategies for the lowland estuary area.

■ Methods

Two sets of available dike and levee GIS data for the Tillamook Bay Basin were obtained. One was created by the TBNEP and the other by the Corps. The Corps' data includes a subset of the levees mapped by TBNEP, but they are mapped with greater accuracy. A new levee coverage, LEVEEMO, was created by augmenting these coverages with information from USGS topo quads. This data coverage includes the levees from the Corps coverage and the levees and roads mapped on USGS topo quads (Figure 6-8-5). Roads were included because they are often built on elevated roadways and, though not labeled as levees on maps, often have the same effects on the movement of water. This new levee coverage was mapped along with historic vegetation and current wetland vegetation (Figure 6-8-6) to illustrate the relationship between levees and changes in vegetative cover.

■ Discussion

Many of the dikes and levees in the Tillamook Bay Basin are located below the MHHW elevation in the estuary. Levees are often used in conjunction with drainage tiles to improve agricultural productivity in tidally influenced areas by protecting land from salt water. Separated from tidal action and exposed to land drainage and grazing, native plant communities were replaced, over time, by non-native communities. Interestingly, some of the vegetation has reverted to its historic community structure. This has likely occurred in areas where the levees were not maintained the reintroduction of salt water inundation was allowed.

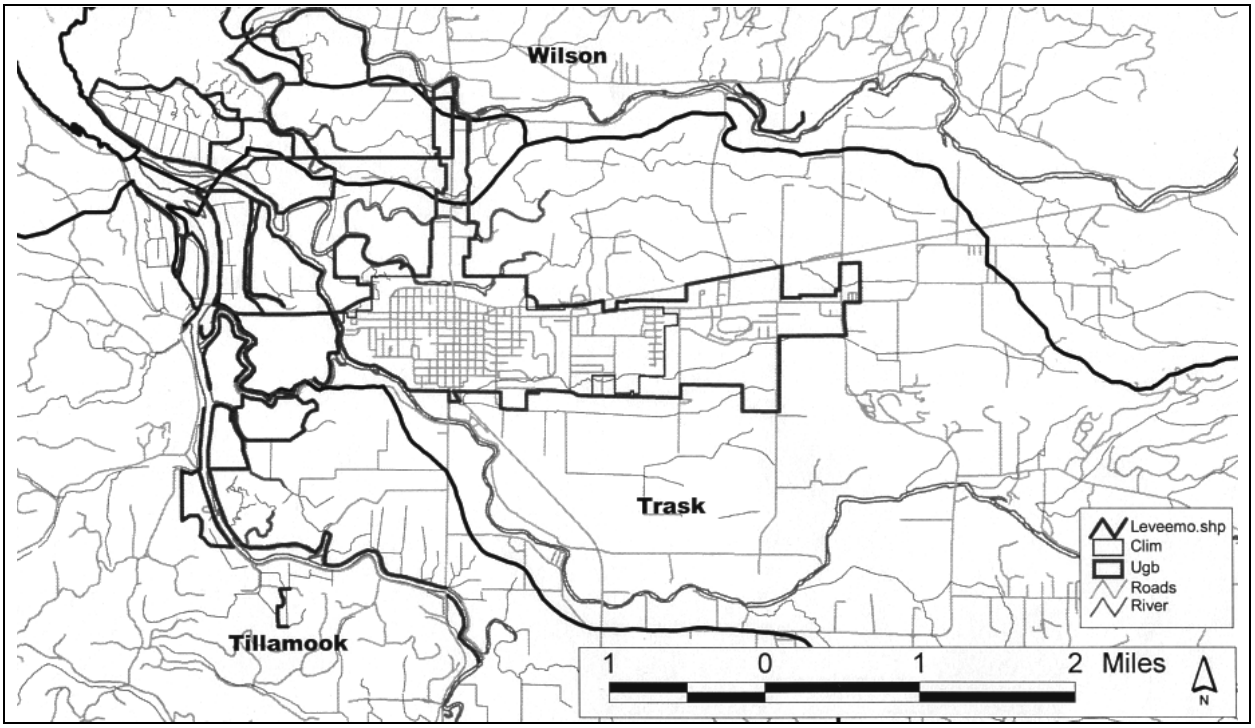

Figure 6-8-5. Lowland Valley Levees and Dikes

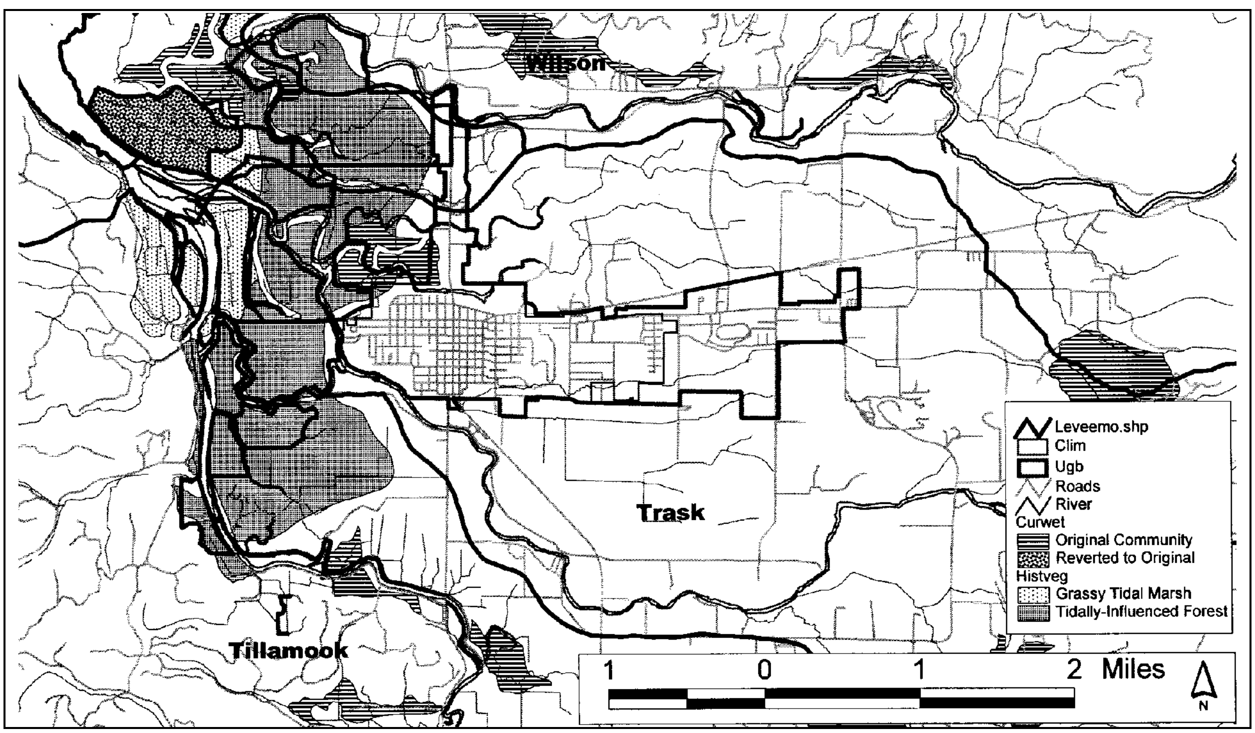

Figure 6-8-6. Levees and Dikes Mapped with Historic and Current Tidal Plant Communities

6.8.4 Post-Flood Permit and Damage Claims

■ Objectives

Increasing development in flood-prone areas, combined with repetitive flood events, have resulted in an increasing number of flood damages and permit requests for waterway work following floods. These post-flood actions often hinder habitat restoration efforts or increase flood risks to neighboring properties. The objective of this assessment was to understand the characteristics of flood damage claims and permit requests in Tillamook County, to determine how permit actions are approved, tracked and archived and to assess how well the permit database information reflects the actual permitting of post flood actions. Based on the findings of this assessment, recommendations are made for streamlining the permit system and improving the accuracy and usefulness of permit data.

■ Methods

Tillamook County flood damage estimates, damages claims and flood insurance data were evaluated from a comprehensive report on flood problems in the county (Levesque, 1980) and from interviews with FEMA Region X staff (Eberlein, 1997). Historic flood damage data were compiled and compared on a common basis using 1996 dollars (Table 6-81). Damage estimates were converted to 1996 dollars by multiplying earlier dollar amounts by a ratio of the respective MEANS Historical Cost Indexes (MEANS, 1997). Flood insurance policies and coverage amounts for 1980 (Levesque, 1980) were compared to those for 1997 (Eberlein, 1997) by local jurisdiction (Table 6-8-2). Claims amounts since 1978 were also itemized by local jurisdiction.

Post-flood permits were evaluated from agency databases including: the U.S. Fish & Wildlife Service (USFWS), the Federal Emergency Management Agency (FEMA), the Corps of Engineers (COE), the Natural Resource Conservation Service (NRCS), and the Oregon Division of State Lands (DSL). Data were obtained directly from permit and database staff through interviews. Permit application forms and data entry practices were compared among the agency databases, and the accuracy of the entries was assessed. The computer hardware and software used for the databases was identified, and the portability of data among agency databases and to PC-based computing systems was assessed. The accuracy and usefulness of the data for quantitative analysis using GIS was evaluated by plotting raw agency data and observing resulting permit locations on maps.

■ Discussion

A comparison of 1996 flood damages to historic flood damages indicates the 1996 event was significantly the most damaging event in the history of the county (Table 6-8-1). Flood insurance policies have more than tripled in Tillamook County between 1980 and 1997, and insurance coverage has increased by nine times to $122 million (Table 6-8-2). The increase in flood insurance policies may be an indication of increasing development in flood hazard areas.

Several agency permit databases exist because of the variation in the jurisdictions of the agencies. For instance, the FEMA database lists actions not in waters of the United States and thus not permitted and recorded by COE or DSL. A compilation of 1996 permit and claim locations in the Tillamook Bay Basin is shown in Figure 6-8-7 for FEMA actions and COE and NRCS permits. Data for this year was loosely assumed to reflect permits and claims related to the February 1996 flood event. Numerous post-flood permits were applied for in Tillamook County. In the Tillamook Bay Basin, these projects tended to be concentrated along the margins of the bay and in the

Table 6-8-1. Comparison of Tillamook County Historic Flood Damages in 1996 Dollars

Flood Year [1]	Flood Damages [1]	Historic Cost Index [2]	Flood Damages (1996 $)[3]
1964-65	$1,632,000	21.2	$8,337,057
1972	$3,303,000	34.8	$10,279,164
1974	$310,000	41.4	$810,942
1977	$4,213,000	49.5	$9,217,533
1996	$53,000,000	108.3	$53,000,000

[1] From Levesque, 1980

[2] From MEANS, 1997

[3] Example 1996 $ = 1974 $ x (1996 index/1974 index

Table 6-8-2. Comparison of Tillamook County Flood Insurance Coverages Between 1980 and 1997 and Claims Since 1978

Area	No of Policies (in 1980)	Insurance Coverage (1980$)	No of Policies (in 1997)	Insurance Coverage (1997$)	Claims Since 1978 (1997 $)
Tillamook County	235	$9,393,700	766	$80,470,600	$1,416,161
City of Tillamook	15	$451,500	91	$10,623,100	$1,451,185
City of Bay City	6	$176,600	8	$722,100	$0
City of Garibaldi	0	$0	2	$693,000	$0
City of Manzanita	15	$572,500	47	$7,889,000	$1,954
City of Nehalem	11	$556,600	27	$3,184,300	$190,881
City of Rockaway	50	$1,960,100	155	$17,281,700	$48,777
City of Wheeler	3	$44,900	3	$685,300	$0
TOTALS	**335**	**$13,155,900**	**1099**	**$121,549,100**	**$3,108,958**

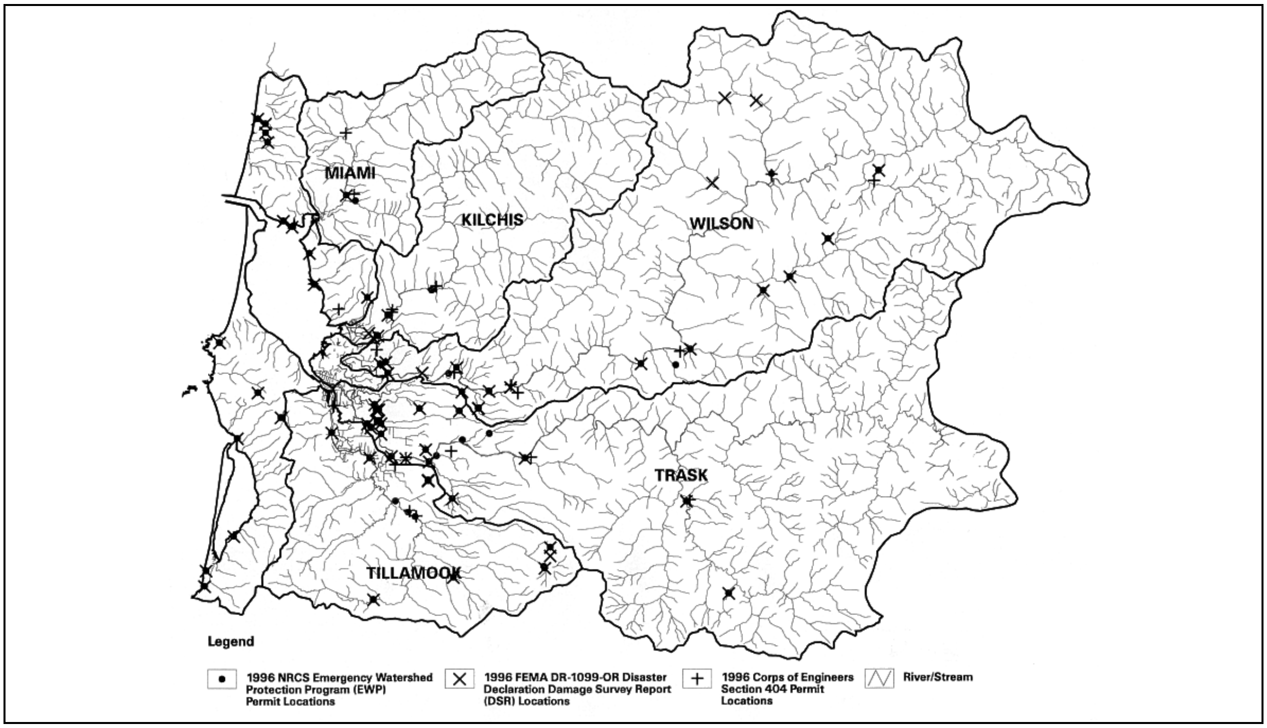

Figure 6-8-7. 1996 Permits and Flood Damage Claims

City of Tillamook and the Wilson River floodplain. Efforts should be made to coordinate or consolidate databases to enable consistency and efficiency in the permit process. The complexity of evaluating cumulative impacts is one of the major reasons why coordination of databases is needed, between agencies which regulate waterway impacts, agencies which evaluate water quality, and agencies responsible for fish and wildlife resources.

Different agencies use different database hardware and software. For instance, USFWS uses Paradox while DSL has used Wang. An agency which does not have Wang cannot access the DSL database unless DSL converts the requested information into a different format, such as an EXCEL spreadsheet. The COE RAMS database is not transferrable to file at all, and can only be used on screen or in print-outs. The NRCS uses a form of spreadsheet which USFWS programs have not been able to import. In many instances, federal agency computing systems were established many years ago, and large databases are still being managed on old mainframe systems, as opposed to PC-based systems that are compatible with microcomputer applications and GIS systems.

In instances where there is a compatible database structure, it is difficult to exchange data because of differing database content. For instance, NRCS does not provide applicant names in public copies of the database, and does not include COE or DSL permit numbers. Therefore, it is difficult to match these records. Some of the databases lack detailed information about actions. The COE database contains latitude and longitude for each action, but not the size of the action. The DSL database records the size of the action, but not its latitude and longitude. It is understood that DSL gave up the lat/long system with consideration of private property rights. A standardized method should be followed by all agencies to record similar data, especially in a format that can be transferred to microcomputers and GIS.

Databases for quantitative analysis should have separate fields for each type of information and should have clear and consistent naming conventions. For instance: River, County, Latitude, and Longitude should be separate fields, rather than having one field for Location. This way, information which is needed for the purpose can be easily isolated, and extraneous information ignored. When information is not thoroughly divided into specific fields, querying also becomes difficult and less useful. Again, a consistent format or one central database would eliminate repetition of data entries and the inability to cross reference data among agencies.

Discrepancies also exist between actual actions and their recorded descriptions. For instance, an applicant is likely to use a different amount of riprap than what was requested in the permit application and permitted. The DSL database has fields for both permitted and completed amounts of fill and removal, but there is virtually no data entered in the 'completed' field. The regulatory program should be expanded to require documentation of the resulting 'as-built' condition, possibly through the use of economic incentives for the permit applicant.

From the databases, it is difficult to study the repetitive damages from flooding. Some databases, such as that of DSL, go back several decades but contain limited information on repeated actions. For instance, it is not evident how many times the same gravel removal permit had been renewed. Other databases only contain records since 1991 (COE) or 1996 (NRCS) because of programmatic changes. Permit databases should be structured in a manner that allows an assessment of repetitive actions and the cumulative impacts of these actions.

A number of problems in the existing databases can impede efforts to create a GIS map which emphasizes the biological significance of actions. DSL's use of section, township, and range results in permit actions being plotted at the center of a section, and not necessarily even appearing associated with any stream. Even with latitude and longitude data, many actions appear to overlap. Another location method used is river miles. These data could be helpful to correlate flood response actions with fish habitat. However, plotting river miles requires that they be measured from the mouth of every stream, and every stream has a River Mile 0, for example. This is in contrast to a more precise measurement such as latitude, which signifies a specific point on the globe. Preparing data for GIS or other forms of analysis is extremely time-consuming and complicated, perhaps needlessly so. A close working connection should exist between field staff, database staff, GIS staff, and project managers so that products can be evaluated at every step of the process and work can proceed efficiently.

The nationwide permit process, under which almost all bank stabilization projects are authorized by the COE, is meant to speed the construction of projects which have minimal environmental impacts, individually and cumulatively. In Tillamook County, 97 percent of the Nationwide Permits issued between 1988 and 1996, during the designated flood disasters of 1990 and 1996, were approved. Whether cumulative impacts are minimal is especially difficult to evaluate for river projects because habitat and habitat impacts are not quantified in acreage as wetland losses are. Under the nationwide permit process, not all post-flood actions which occur receive permits. Rural areas are especially likely to have large waterway impacts that go unnoticed by regulatory agencies. The nationwide permit process should be reviewed to assess the criteria for permit approval, the implications of the process on cumulative effects, and the opportunities for using data from the process to evaluate cumulative effects.

6.8.5 Public Policy Assessment

■ Objectives

The intent of the public policy component of the Tillamook Integrated River Management Strategy (IRMS) is to develop the context in which to implement the three underlying objectives:

- restoration of floodplain functionality
- reduction of flood impacts
- improvement of aquatic and terrestrial habitat

The scope of the public policy assessment was originally intended to review all plans and government-administered activities which impact the three main objectives. The focus was fairly clear as to the limited number of polices which potentially impacted these objectives. However, soon after the review of the target policies and programs began, it became clear that the specific items as mentioned were not the crux of the key issues. For example, the Goal 7 update process is not only significantly behind schedule, but its scope is also being modified. Another example is the Oregon Plan, which relies heavily on current permitting and review processes.

Thus, after a preliminary review of key policies, it was determined that the first step must be an inventory of policies currently in effect for the study area. The term 'public policy' was broadly defined to include a wide range of activities to accomplish such tasks as:

- problem identification (hazard analysis, water quality degradation, etc.)
- data analysis (GIS based inventories, etc.)
- development of planning goals (CZM project, NEP, etc.)
- adoption of plans (county plans, Oregon Plan, etc.)
- adoption of regulations and permits (404, 402, building permits, etc.)

After defining the scope to cover all of the above types of "policies" it became clear that the array of policies and permits in the generalized area encompassed by the IRMS is vast. Most, however, do not explicitly address the floodplain, and do not necessarily explicitly address the IRMS goals. Nonetheless, each policy has important impacts on the areas of concern of the three original objectives. Conversely, tools which are in effect have not been structured to implement the key objectives, e.g. NEPA. Finally, major efforts in effect for our study area are only indirectly impacting the actual public policies, e.g. NEP, but such projects do not explicitly promote implementation because they have no legally binding status.

■ Methods

Since the public policy assessment was intended to clarify the complex federal, state and local policy environment, an initial effort was made to inventory the 54 programs impacting the IRMS. The inventory was prepared in spreadsheet format (Table 6-8-3) in order that entries could be accessed and sorted into seven categories:

1. **Level.** Programs promulgated at federal, state, and local levels were identified.
2. **Responsible Agency.** The specific agency within the federal, state or local levels were identified.
3. **Spatial (geographic scope)**. The spatial scope of the each policy was defined (surface waters, flood plain etc.). In many cases the spatial context of the policy has not been explicitly defined, i.e. the polices were aspatial as written; however as they become implemented they impact a specific spatial area, e.g. Tillamook basin.
4. **Purpose.** Underlying intent of the program.
5. **Program Authority**. Policies adopted by law have legal/implementation authority, while plans tend to be advisory where

implementation is discretionary. In general, laws and regulations are promulgated at the federal level. They are, however, administered at the state level, and are in many cases implemented at the local level.

6. **Trigger Activity**. In many cases an action results in the requirement for compliance with specific programs or regulations, i.e. they will trigger the need for a permit. An emphasis of this inventory has been on the legal context of requirements.

7. **Key Issues.** Key issues were defined in relation to concerns of the IRMS primary objectives. The issues and the number of policies reviewed in each category are listed below:

   (4) Access/NEPA
   (11) Flood Hazard Reduction
   (2) Floodplain Management
   (14) Water quality
   (8) Watershed Planning
   (10) Habitat
   (1) Land use planning
   (1) Terrain analysis
   (2) Water availability

▪ Discussion

Review of the accompanying inventory leads to a number of conclusions.

1. **Policy is highly fragmented.** Broad investigative actions are initiated at the federal level. Authority for review is at the state level; while administration of permit granting and decision making is at the local level. Although 54 separate policy items were reviewed, the inventory is dramatically incomplete and does not give a holistic view of the planning status for the area.

2. **Policies are generally advisory, while permit requirements are legal tools and are only tangentially related to polices.** The most comprehensive planning programs do not have the status of law e.g. NEP, CZM. Conversely, existing permit authorities are currently being used to achieve objectives significantly different than the underlying intent of the permitting authority.

3. **Disconnect exists between plans and regulations.** There appears to be a continuity gap between plans and regulations. The most prevalent forms of permits pertain to fill and dredging. The intent of the these permits does not correspond to any of the three objectives, yet they have the most significant impact on the geographic/spatial area (integrated river system) under study.

GIS data sets being developed by various planning efforts do not necessarily support planning or regulatory need which would facilitate the three policy objectives.

Future efforts should be made to complete this document by reviewing the existing implementation profiles (including 404 and other permits) in light of both their original intent and current planning goals e.g. Essential Fish Habitat goals. The underlying objective should be to ascertain whether the existing permit structure needs to be modified in light of current concerns. Related efforts should look at flood control efforts such as diking practices and removal-fill agreements in light of current ESA and related issues.

Table 6-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Oregon Coastal Salmon Restoration Initiative, aka The Oregon Plan (for Salmon and Watersheds)	Consortium	Upper Tillamook Watershed	State response to salmon restoration issue. Oregon State authority under Constitution Article V, Sections 1 & 13	Endangered Species Act as enforced by National Marine Fisheries Service (NMFS) Authority		Watershed
Tillamook Bay National Estuary Project (TBNEP)	Consortium	Bay	NEP est. in 1987 by amendments of the Clean Water Act to identify, restore and protect estuaries along the coasts of the US ; Local NEPS develop partnerships between gov't agencies that oversee estuarine resources and ppl who depend on the estuaries.	Data Collection : GIS data layers Inventory List (active and archived, ARC/Info export files) available at osu.orst.edu/dept/tbaynep/archive.html & osu.orst.edu/dept/tbaynep/active.html ; Base Programs Analysis available from this office	Directs the Comprehensive Conservation Management Plan: Curren mandate- to address 3 priority problems: critical habitat loss; sedimentation; bacterial contamination. The Mgnt committee is considering adding "Flooding" as a 4th priority problem.	Habitat
Tillamook Coastal Watershed Resource Center	Consortium	Watershed	Collaborative effort of the Tillamook Bay Community College, the Economic Development Center of Tillamook, the Tillamook Bay NEP, and the Soil and Water Conservation District of Tillamook.	State Watershed Council	N/A	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Eligibility for flood insurance to communities that adopt approved floodplain management regulations	National Flood Insurance Act (NFIP)	Participation in NFIP requires minimum floodplain management regulations	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Funds projects which will result in long term impacts and produce repetitive benefits over time. Must have 404 Hazard Mitigation Plan	Hazard Mitigation Grant Program.	Presidentially declared disaster	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Post disaster infrastructure repair	Public Assistance (for public facilities)	Presidentially declared disaster	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters		Section 404 waterway permits. Dredging and filling which may affect water quality.	Work affecting navigable waters, tributary streams, & wetlands (considered special aquatic sites)	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters	Permits administered by DSL ; USFWS & NMFS also review permit applications (advisory function); also requires (State) 401 certifications for mitigation of impacts to fish and wildlife; EPA review for 404(b)(1) compliance with CWA	Section 404 permit (Joint with DSL) ; and Section 401 Water Quality Certification	Work affecting navigable waters (tidal and fresh), tributary streams, & wetlands (considered special aquatic sites)	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters	Preserve navigability of nation's waterways, regulates activities within ordinary high water mark	Rivers and Harbors Act, Section 10 permit (administered through DSL)	All work affecting navigable waters: construction of dock and in-water structures, placement of pilings.	Water quality, Flood
U.S. Bureau of Land Management	Federal					Habitat
U.S. Department of Fish & Wildlife	Federal	Watershed	Review US COE permits for mitigation of impacts to fish and wildlife (advisory function)	Fish and Wildlife Conservation Act		Habitat
U.S. Department of Fish & Wildlife	Federal	Watershed		Tillamook Bay Flood Systems Analysis		Habitat
U.S. Department of Fish & Wildlife	Federal	Navigable waters	Granting agency ; Advisory role - specific to individual projects	Section 10 & 404 Permits (Joint with DSL); all 404 permits are also subject to Section 401 Water Quality Certification by DEQ	Fill activity in navigable waters	Habitat
U.S. Environmental Protection Agency, Region X	Federal	Surface waters		National Estuary Projects (a section of the Clean Water Act) fall under general oversight of the EPA Office of Water		Habitat
U.S. Environmental Protection Agency, Region X	Federal	Surface waters	Review of NPDES permits and NPDES Storm Water Permit 1200-C	Regulates storm water discharges into surface water bodies under 40 CFR, Sect. 122-124		Water quality
U.S. Environmental Protection Agency, Region X	Federal	Surface waters	Policy making authority in Tillamook; member on Policy Committee for TBNEP			Water quality
U.S. Geological Survey (USGS)	Federal	Shore	Topographic, geological and water resources data collection	Educational; data collection		Terrain
U.S. Geological Survey (USGS)	Federal	Surface waters	TBNEP contracted with the USGS for installation of tidal gauges data collection from Wilson & Trask Rivers.			Water quality
U.S. National Marine Fisheries Service (National Oceanic & Atmospheric Administration) (NMFS)	Federal	Water bodies	Review US COE permits for mitigation of impacts to fish and wildlife	Fish and Wildlife Conservation Act	Administration of certifications and permits delegated to Oregon DEQ	Habitat
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	River basin	Provides planning assistance for development of coordinated water and related land resource programs. Priority: upstream rural community problems w/ wetlands preservation	Cooperative River Basin Program		Watershed planning
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	Stream banks	Technical & data collection assistance to Water district cooperators ; Performs watershed inventories and assessments	Advisory ; Educational		Habitat
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	Watershed	Assists local governments to make repairs which reduce threat from future flood events to private property	Emergency Watershed Program (EWP) Permit		Watershed protection
Tillamook County Community Development Department	Local		Administers NPDES permits	Tillamook County Land Use Ordinance		Water quality
Tillamook County	Local	Project	Municipal authority		Sources which discharge wastewater to a municipal sewer have no permit requirements from DEQ, but may be affected by municipal discharge and pretreatment requirements	Water quality
Tillamook Watershed Council	Local, Voluntary	Watershed	Established by the Governor's Office to improve the condition of watersheds in their local area. Represents a balance of interested and affected persons within the watershed	Advisory function ; Coordinates various involved agencies	N/A	Watershed
Interrain Pacific	Non-profit	Tillamook Bay	Educational, Data Collection, Provide training & GIS tech support, Assist in watershed assessment/monitoring programs.	NEP support	Contracted by EPA to provide GIS data for Tillamook Bay NEP	Watershed

Table 6-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Office of Emergency Management (OEM)	State	County	Administers FEMA's mitigation programs, including 404 hazard mitigation programs	State Hazard Mitigation	Declared disaster	Flood hazard
Oregon Department of Consumer & Business Services, Building Codes Division [DCBS]	State	Structure		1996 Oregon Manufactured Dwelling Standard (OMDS), Section 308 requires manufactured dwelling parks to be 12" above the base flood level or 3' above finished grade, whichever is less.	FEMA regulations [44 CFR Chapter 1, Section 60.3(c)(6)(iv)] requires manufactured dwellings substantially damaged from the 1996 Oregon floods be elevated to or above base flood level.	Flood Hazard
Oregon Department of Environmental Quality [DEQ]	State	Project	Structural measures impacting surface water requires water quality certification and/or modification. Sources which discharge to land but also discharge to surface waters part of the year must obtain a NPDES Permit.	Clean Water Act, Section 401 Certification of Water Quality Compliance required prior to any in-water disposal	Clean Water Act Section 401 applies to any activity which may result in a discharge to waters of the state (ex.: land uses such as agriculture, mining, ports, transportation projects, industrial siting/construction and operations)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project	Water Quality Program concentrates on protecting the "beneficial uses" of Oregon's water , and preventing pollution through education, training, and regulation	National Pollution Discharge Elimination System (NPDES) Permit, Individual. Issued under the Federal Water Pollution Control Act and OAR 340-45-005 through 340-45-065 ; the EPA may review the permit during the public notice period	Point source discharge of pollutants into surface waters. Construction activities: clearing, grading, excavation which disturb 5 or more acres, and development which disturbs al least 5 acres over a period of time	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project	Several municipalities are issuing the construction permits for DEQ, processing/application times may differ. Generally it is part of the process required to obtain a building permit	National Pollution Discharge Elimination System (NPDES) Permit, General	Issued to cover categories of minor discharges when an individual permit is not necessary to adequately protect water quality (ex.: fish hatcheries, log ponds, seafood processing, petroleum hydrocarbons cleanup, vehicle wash water)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project		Clean Water Act, Section 402 NPDES Storm Water Discharge Permit 1200-C, General	Storm water discharges associated with industrial activity listed by the EPA and which involve storm water which leaves the site through a "point source" and reaches surface waters either directly or through storm drainage	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Large sites	Issued under of ORS 486B.050, OAR 340-14 and OAR 340-71, and in accordance with OAR 340-40	Water Pollution Control Facilities (WPCF) Permit, Individual	Issued for systems which disposes of wastewater with no direct discharge to surface water (ex.: land irrigation systems, evapotranspiration lagoons, industrial seepage pits, on-site disposal systems with 2,500+ gal/day wastewater flows)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Stream		303d water quality - limited streams and lakes		Water quality
Oregon Department of Forestry	State	Watershed	Technical Assistance, Notification of Operation	Authority under the Forest Practices Act	Required prior to beginning a forestry operation	
Oregon Department of Forestry - Tillamook River Watershed	State	Stream	Water quality monitoring - Tillamook River watershed			Watershed
Oregon Department of Geology & Mineral Industries (DOGMI)	State	Shore	Landslide analysis ; Administration of Tsunami Inundation Zones	Review		Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Administers National Flood Insurance Program (NFIP)			Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Works w/ Tillamook County in an advisory capacity to help them remain compliant w/ zoning ordinances & the statewide goals			Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	State Land Use Planning authority ; Preparing administrative guidelines for Goal 7	Administers State Land Use Law		Land use
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Administers federally approved Coastal Management Program	Administers the National Estuary Project (NEP)		Water quality
Oregon Department of Transportation	State	Roadways	Responsibilities are project-specific. Current project in Tillamook: Wilson River Dougherty Flue on Hwy 101 (N. end of Tillamook)- re: Road widening & impact on wetland ditches	Construction permits		Access
Oregon Department of Transportation	State	Roadways	Technical/design assistance to city and county road projects ; Not participating in TBNEP	Review		Access
Oregon Department of Transportation	State	Roadways	Serves as an instrument of the FHWA when channeling federal funds for city/county projects			Access
Oregon Department of Transportation	State	Roadways	Environmental Research Unit, Wetlands Team	National Environmental Policy Act (NEPA)		Access
Oregon Division of State Lands	State	Water bodies	Authority under the state's Removal-Fill Law. USFWS, NMFS and Oregon DFW also review permit applications (advisory function) ; requires (State) 401 certif. for mitigation of impacts to fish and wildlife; & EPA review for 404(b)(1) compliance with CWA	Fill & Removal permit, aka Removal-Fill Permit, aka Dredge & Fill 401 Certification, aka Section 401 Water Quality Certification (All sect. 404 Permits are also subject to this req.) A Joint DSL/USCOE permit which is next forwarded to DEQ for review	In any wetland - to remove from or place fill into state waters, 50 cubic yards or more of material, i.e. to dredge, fill, or otherwise alter a waterway. Generally, projects that impact wetlands/waters require this permit	Floodplain
Oregon Division of State Lands	State	Channel	In-water structures	Section 10 permit (Joint with DSL)	Work affecting navigable waters: construction of dock and in-water structures, placement of pilings, dredging & filling [Both 10 & 404 permits required for fill activity] which may affect water quality	Floodplain
Oregon Division of State Lands	State	Channel	Erosion Control General Authorization	General Authorization for Wetland Restoration & Enhancement		Habitat

Table 6-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Oregon Division of State Lands, joint with U.S. Army Corps of Engineers	State	Rivers, Streams, Wetlands	Regulates the discharge of dredged or fill materials. Projects in which the applican will dredge, fill, or otherwise alter a waterway requires a Joint DSL/USCOE permit (which is next forwarded to DEQ for review).	Clean Water Act, Section 404 Dredge and Fill Permit		Water quality
Oregon Water Resources Department	State	Rivers	Distribution & regulation of water rights; Generally has authority over anything re: water use or quantity.	Permit to Appropriate Surface Water	Appropriation/storage/use of surface water	Water
Oregon Water Resources Department	State	Basin		Permit to Appropriate Ground Water	Appropriation/storage/use of ground water	Water
Oregon Water Resources Department	State	County	Because of the Salmon Plan Initiative, regional area coverage is changing to have the rivers and their related watersheds covered by a single region; Tillamook county is the new site of a regional office formerly based in St. Helens.	Tillamook Office has a contract with the TBNEP to install and collect flow measure data on stream gauges in Miami, Tillamook & Kilchis Rivers		Watershed
Oregon Water Resources Department	State	Rivers		Water Diversion Structure Permit		Watershed
Oregon Department of Fish & Wildlife	State	Riparian Corridor	Formulates general state programs and policies for mgmt & conservation of fish and wildlife resources.	Clean Water Act, Section 402 and 404. Administration of permits delegated to DEQ.	Reviews NPDES, sect. 10 & 404 permits for mitigation for impacts of activities/development; Provides research/technical assistance.	Habitat

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7. Constraints and Opportunities to Developing an Integrated River Management Strategy

7.1 Introduction

In this section we evaluate constraints and opportunities to developing an Integrated River Management Strategy, with respect to natural processes and human land uses within the river system. The previous section provided a number of independent spatial and non-spatial assessments of hydrologic, biologic and institutional elements comprising the Tillamook Bay river system. These assessments were selected from a larger set of assessments detailed in Appendix A. This chapter combines selected individual assessments to accomplish the following:

- divide the Tillamook Bay Basin landscape into management areas based on physical processes;
- describe how the natural and human environments inter-relate;
- where possible, locate functionally important or sensitive areas within the river system;
- spatially identify constraints and opportunities for managing the system in an integrated way.

The dynamic and complex relationships between human land uses and natural processes were simplified into generalized features of the natural and human environment, in order to divide the Tillamook Bay Basin landscape into management areas. These management areas were then divided into discrete landscape zones, based on the spatial extent of common natural processes and landforms. Ultimately, the landscape zones provided a logical breakdown of the river system for assigning common river management actions. The zones also provide a means to prioritize the actions as part of the IRMS itself.

To identify specific constraints and opportunities, selected human land uses, such as roads, stream crossings, dikes and levees, presented in the previous chapter, were spatially overlaid in different combinations on the landscape zones. The resulting composite mapping showed how the natural and human environments interrelate spatially, and allowed a visual evaluation of some of the constraints and opportunities for developing an IRMS. This evaluation provided the foundation for the development of the planning level recommendations that make up the IRMS, Non-spatial constraints and opportunities were also evaluated from a public policy standpoint.

This chapter ends with a possible future vision of the Tillamook Bay river system, if an integrated system-based approach is not taken. This view is intended to articulate potential lost opportunities and increasing constraints as time continues and the river system continues to be managed as it has been. This hypothetical scenario leads into the discussion of an alternative future scenario for the river system in the next chapter. A comparison of these two future scenarios provides a basis against which the benefits and values of an integrated approach to managing the river system can be measured.

7.2 Tillamook Basin Spatial Zones

7.2.1 Management Areas

Within the river system, the physical structure of the natural environment and the features of human land use were initially evaluated by breaking the landscape down into generalized features of the landscape and land use. Many of the land uses within the basin are confined to specific physical landscape features. For example, agriculture dominates the flatter lowland areas while forestry prevails on the steeper slopes. By spatially dividing the basin based on land use and physical features, the relationships between specific land uses and natural processes are revealed. In some cases, land use and natural processes conflict, while in others there is a more beneficial relationship.

The river system was initially divided into the general physical features of bay, estuary, lowland and upland. The extent of these physical features is schematically shown in Figure 7-1. The bay was assumed to extend up to the limit of Mean Lower Low Water (MLLW). The estuary was considered as land extending above MLLW to Mean Higher High Water (MHHW). The lowlands generally extend from MHHW to the natural change in slope between the lowland valley and the uplands. The uplands extend from there up to the boundaries of the watershed.

The varying physical features of the basin provide varying opportunities for human use of natural resources throughout the river system. They help to sustain the economy and lifestyle of the residents of, and tourists to, the area. Human use of the land initially evolved with recognition of constraints imposed by the natural environment, such as flooding. Flooding still represents one of the predominant natural constraints to human land use in the river system. Conversely, it represents one of the best natural opportunities for recovery of salmon. Seasonal flooding, which helped to shape the lush lowland landscapes that have attracted human populations over the centuries, has also sustained salmon populations over the millennia.

Recent work by Smith (1999) addresses human land use within the river system and the jurisdictions of the institutions dealing with salmon issues in the Tillamook Bay basin. Figure 7-2 shows a generalized division of these interests and their extent. The varied ownership and land uses within the river system impart constraints to the management of the river system as a whole. For example, upland public and private forest land uses are governed by forest practices rules of the Oregon Forestry Board; lowland agricultural land uses are administered by the Oregon Department of Agriculture; and lowland urban land uses are overseen by the local incorporated and unincorporated governments. The goals and objectives for managing the land for flood risk reduction and salmon recovery by the different institutions often do not coincide or are not coordinated. As Smith (1999) notes, "this spatial fragmentation…suggests weak power to obtain desired actions."

Human land use is more intense in the lowlands. Interventions are more prevalent and significant in this part of the river system, and the potential for flood and fish impacts is greater. Obstacles to the development of an IRMS are more prevalent and inflexible here, because of the longevity of the human presence and established infrastructure. Opportunities include features and processes of the natural environment that, if allowed to function in a natural manner, would demonstrate the natural resiliency of the river system.

7.2.2 Tillamook Basin Landscape Zones

The management areas of the landscape were further refined into landscape zones. The landscape zones reflect in more detail the natural processes occurring in the river system. The upland, lowland and estuary landscape zones and the methods for their development are described below and mapped in Figures 7-3 and 7-4. These spatial zones were considered in the evaluation of constraints and opportunities to the development of an IRMS.

Upland Management Area:

1. Forested zone. This zone represents the general extent of the western hemlock/Douglas fir forest. This zone was defined as land area above 500 feet in elevation.

2. Transition zone. This zone was defined as land area below 500 feet elevation and above the elevation of the FEMA 100-year floodplain. This area generally corresponds to the landscape historically dominated by Sitka spruce forest.

Lowland Management Area:

3. Floodplain zone. A majority of the lowland valley area was defined as the floodplain zone. This zone corresponds to the regulatory FEMA 100-year floodplain. The use of the FEMA floodplain boundary to define this management area results in a smaller area than would be obtained if the lowlands were defined by the natural change in slope between the lowland valley and the steeper upland terrain. However, this delineation is considered appropriate for this work because it focuses attention on the more dynamic and functional portion of the lowlands that experiences more frequent flooding.

The floodplain zone is above normal tidal influences, but includes areas that are inundated by extreme tidal storm surges. As such, it includes areas located between MHHW (4.2 feet, NGVD) and 10.0 feet, NGVD. The latter elevation is the 100-year stillwater elevation adopted from the FEMA flood insurance study for Tillamook County, and represents an extreme tide level from the combined effects of an astronomical high tide and storm surge that has a 1 in 100 chance of happening in any given year. Tidally-influenced river reaches are included in this zone and extend inland within the banks of the mainstem river channels up to the heads of tide. The head of tide represents the inland extent of normal tidal influence on river water elevations.

4. Active floodplain zone. This zone is located within the FEMA 100-year floodplain and represents river reaches, and their associated floodplains, that are considered to be actively meandering. This zone was determined by evaluating bank stability and comparing the relative change in historic channel planform patterns.

Estuary Management Area:

5. Tidal zone. This zone extends from MLLW (3.8 feet, NGVD) to MHHW (4.2 feet, NGVD). MHHW represents the average height of the higher high tides and can be characterized in the field as the transition between low marsh and high marsh vegetation. High marsh vegetation could be expected inland to an elevation of about 10 feet. Both the MLLW and MHHW elevation contours were delineated using a 10-meter (33-foot) DEM. This zone consists primarily of intertidal habitat and includes both salt and brackish water aquatic ecosystems.

The tidal zone is divided by the brackish/freshwater interface (Figure 7-4). Though the natural process of tidal inundation is the same on both sides of this interface, the habitats supported in the brackish and fresh water zones are unique.

6. Subtidal zone. This zone is below the elevation of MLLW (3.8 feet, NGVD). It includes the open water habitat of the bay and tidal channels that are deep enough to remain inundated at all tidal elevations.

7.3 Spatial Evaluation of Constraints and Opportunities

In this section, selected spatial features of salmon distributions and habitat, and human land uses (e.g. roads, stream crossings, dikes and levees), are overlaid in different combinations at the basin extent and the lowland valley floodplain extent. The maps are intended to integrate key assessments from the previous chapter to define spatially the constraints and opportunities for the development of an IRMS in the Tillamook Bay Basin. The selected maps support some of the significant conclusions from this study, which are italicized as headings in the following sections.

7.3.1 Constraints and Opportunities in the Uplands

Salmon are distributed throughout the Tillamook Bay river system.

Constraints: Figure 7-5 provides a map of salmon distributions in the Tillamook Bay Basin overlaid with selected vegetation zones. The distribution of individual fish species is indicated by progressively thinner lines on the map, so that overlaps in distribution can be seen. A larger number of species utilize the lowlands and lower portions of the uplands; however, multiple species are distributed among the headwater reaches of the uplands. This wide geographic distribution of salmon within the drainage network implies that salmon can be affected by human activities nearly anywhere in the basin.

***Opportunities**:* The fact that nearly all the mainstem rivers and major tributaries are accessible to salmon means that there are abundant restoration opportunities in the area. Priority should be given to recovery efforts where multiple fish and other species are present, and where watershed conditions are relatively intact. Emergent and forested wetlands in the brackish-freshwater transition area of river systems should be prioritized for restoration because these areas are important for juvenile salmon rearing and acclimatization to salt water (Northwest Fisheries Science Center, 2001).

Opportunities for large-scale salmon recovery may be most practical where species diversity and availability of productive habitat exists on public lands.

Constraints: Large-scale salmon recovery efforts on private lands may face difficulty because of the variety of land ownership, land uses and land management techniques. Ecosystem restoration is most effective if actions are implemented at a watershed scale, without the constraints of imposed property boundaries.

Opportunities: Opportunities for large-scale salmon recovery efforts in the uplands exist where salmon habitat exists on public lands. A GIS-based analysis was performed to identify and rank opportunities for watershed conservation with consideration given to habitat abundance, species diversity and patterns of land ownership. The method used in this spatial evaluation is described below.

Many watersheds or stream corridors within the Tillamook Bay basin have already been recognized in previous regional scientific assessments as particularly important to salmon and other aquatic species in the near term. These include Aquatic Diversity Areas (ADAs) identified by the Oregon Chapter of the American Fisheries Society (Li et al. 1995), federal Key Watersheds (FEMAT 1994), and Core Areas mapped by the Oregon Department of Fish and Wildlife (OCSRI 1997). These previously-identified important areas were combined into a group of nine watersheds worthy of near-term emphasis in aquatic conservation. The watersheds were delineated to include the Oregon Chapter's ADAs, federal Key Watersheds, and other catchments that have relatively high densities (mi/mi2) of ODFW Core Areas. After identifying the nine priority watersheds, GIS-based analyses were conducted to develop values for a variety of metrics related to salmon and watershed conditions. The analyses were based on spatial data layers readily available from public sources. Metrics developed for each priority watershed included drainage area (mi^2); abundance (mi/mi^2) of Core Areas; abundance of habitat for native coho, chum, fall chinook, spring chinook, and winter steelhead; and the percent of publicly-owned land. These metrics were then used to rank the relative priority of the watersheds by following a three-step process similar to that outlined by Huntington and Frissell (1997).

1. Regional Biodiversity Value. Watersheds designated as federal Key Watersheds, AFS ADAs, or reserves in Noss's (1993) Coast Range conservation plan scored 10000 on this criterion and watersheds failing to meet this selection criterion were given no score. This was intended to identify those watersheds of relatively higher regional importance to terrestrial species, in better condition than adjacent watersheds, or with greater restoration potential.

2. Salmon Value. The relative importance of a watershed to salmon conservation was calculated from normalized values scaled 0 to 100 for metrics on the abundance of ODFW core areas and on the abundance of habitat for each of five species of salmon found in the basin. The algorithm used in the calculations was intended to emphasize the importance of productive habitat and of species diversity. Salmon value was calculated as follows:

Salmon Value = ((normalized abundance of ODFW core areas) + (mean of normalized utilization values for all five species of salmon))/2

3. Salmon Conservation Priority. The influence that conservation on public lands could have on salmon and their ecosystem should be related to the proportion of the landscape in public ownership, because large blocks of state or federal land can be more comprehensively committed to conservation purposes than traditionally managed private lands. The relative conservation priority of each watershed was calculated as the score assigned for its Regional Biodiversity Value plus the product of its Salmon Value (from 2.) and the percent public ownership:

Salmon Conservation Priority = Regional Biodiversity Value + (Salmon Value) x (Percent public ownership)

Salmon Conservation Priority scores were developed for each of the nine priority watersheds within the basin (Table 7-1). Scores ranged from 1164 for the Tillamook watershed with only 14% public land to as high as 14835 for the Kilchis watershed, an Oregon AFS ADA with 90% public ownership. These watersheds are shown on Figure 7-6. The more darkly shaded watersheds are those having been previously recognized as having a high Regional Biodiversity Value. The Tillamook watershed had the highest Salmon Value score but scored low on Conservation Priority because of limited public ownership. This makes it an area where conservation efforts by private landowners and local watershed groups will be particularly important. Historically, lower elevation habitats were some of the most productive areas for salmon, but they are now typically degraded from land use activities and separated from healthy ecosystems (Nehlsen, 1997). The lowland river reaches tributary to the upland priority watersheds for salmon recovery (Figure 7-6) should be prioritized for short term actions to restore connectivity to the uplands.

Table 7-1. Salmon conservation priority scores for watersheds in the Tillamook Bay Basin

		Normalized values								
		Core Areas and utilization by species						Salmon	Percent	Cons. Priority
Rank	Watershed	Cores	Coho	Chum	ChF	ChS	StW	Value	Public	(score)
1	Kilchis R.	34	69	48	96	87	71	54	90	14834
2	N.Fk. Trask R.	62	58	0	43	100	38	55	77	14221
3	Little N.Fk. Wilson R.	31	49	39	100	0	45	39	97	13759
4	Miami R.	55	85	100	76	0	80	62	56	13428
5	Devil's Lk. Fk. Wilson R.*	71	89	0	42	36	67	59	80	4702
6	Cedar Cr.*	53	37	0	69	0	60	43	100	4289
7	S.Fk. Trask R.*	22	83	0	89	92	63	44	87	3789
8	North Fork Wilson R.*	46	46	0	58	0	60	40	71	2806
9	Tillamook R.*	100	100	86	63	0	100	85	14	1164

* watersheds not previously recognized as having a high Regional Biodiversity Value (not Key Watersheds, parts of reserves recommended by Noss (1993), or Oregon Chapter AFS ADAs)

The location of human infrastructure intersecting the river system occurs throughout the uplands and lowlands.

***Constraints*:** The location of upland activities for flood risk reduction and salmon recovery may be partially guided by an understanding for the location of human infrastructure intersecting the river system. As an example, consider the spatial distribution of roadway stream crossing and water diversions shown in Figure 7-7. Floodplain stream crossings, many associated with logging roads, extend throughout the watershed and are primarily concentrated in the Wilson River floodplain and along the Highway 101 corridor. Water diversions are evident along the entire length of the Trask and Kilchis Rivers, and near the head of the lowlands along the Wilson and Tillamook Rivers. As expected, diversions are not located in or near the estuary because of the presence of brackish water in the river channels and groundwater. These points of existing infrastructure may represent constraints to flood risk reduction and salmon recovery efforts. These constraints in the uplands are significant because if they are not addressed, IRMS efforts taken in the lowlands and estuary may be compromised by excessive amounts of water, sediment and organic materials transported down the river system.

***Opportunities*:** A spatial understanding of the distribution and condition of road crossings and water diversions may enable an effort to consolidate these encroachments in the river system. Efforts to decommission old logging roads can be guided by upland salmon habitat distribution and flood potential. Opportunities for conservation and restoration of the river system might be prioritized where this infrastructure is not as prevalent, such as in the Kilchis River basin and the upper Trask River basin.

A majority of the channel reach morphology throughout the Tillamook Bay Basin is steep-sloped and debris-flow dominated, but discrete transitions to fluvial-dominated reaches exist where sediment transport may be managed.

Constraints: Upland land slopes were classified in Chapter 6 into zones of source, transport and response. Slopes between 3 and 10 percent can be generalized as a step-pool channel reach morphology for Pacific Northwest rivers (Montgomery and Buffington, 1997). These reaches constitute the upper limit of the transport zone, where fluvial processes dominate and are contiguous upstream to the lower limit of debris-flow dominated processes. This slope class was mapped using a GIS and a 10-meter Digital Elevation Model (DEM), and the step-pool channel morphology was assumed to occur within land areas identified in this slope class (Figure 7-8). These channel reaches are characteristically confined by valley walls, and may receive direct sediment loads from hillslope failures. Many species of salmon are distributed throughout these reaches (Figure 7-5) and, consequently, these reaches may represent critical areas in the basin where sedimentation may first impact salmon habitat.

Opportunities: It is apparent from a map of this slope class (Figure 7-8) that the lowlands and many locations along the mainstem rivers are fringed by this type of reach morphology. The step-pool reaches in the uplands may be considered as opportunities within the river system where the movement of sediment and wood from debris flows may be attenuated as a part of restoration efforts.

As development pressures continue in the watershed, it becomes increasingly important to preserve or restore the natural morphology of the river system to achieve a more natural rainfall-runoff relationship. Otherwise, as the effects of development accumulate, the Tillamook lowlands may experience progressively larger floods.

7.3.2 Constraints and Opportunities in the Lowlands and Estuary

There is an extensive amount of infrastructure in the lowland floodplains.

Constraints: Figure 7-9 shows the major linear features, such as roads and railroads, dikes and levees, that intervene on the lowland floodplain. These land use features are overlaid on a map of the lowland and estuary landscape zones described earlier. The 100-year floodplain is also delineated, to show the relationship of these lowland features within the floodplain. Road and levee networks are spread throughout the area. Lateral constraints on the river channels from these features tend to increase in a downstream direction. Few roads are located near the channels where they first enter the lowlands. Roads and railroads run parallel to and cross the rivers within the 100-year floodplain zone. In the tidal zone, there are few roads but numerous dikes and levees that constrain the river channels and tidal inundation.

Opportunities: The lack of infrastructure in the upper reaches of the lowlands, in the active channel landscape zones, provides opportunities for managing delivery and deposition of sediment and organic matter from the uplands, before these materials reach the more encroached areas of the lowlands further downstream. These areas are primarily in agricultural production, so management actions should be taken to reduce flood risks to this land use, while allowing for the restoration of natural processes for ecosystem recovery. This may include actions to localize the deposition of fine sediments that would otherwise spread across pastureland and fields and ruin crops or soil conditions. This zone also corresponds to reaches of meandering channel and erosion-prone riverbank soils. The lack of infrastructure aligned parallel to the river channels may provide economical opportunities for setbacks and terracing of the floodplain. These may be lost if future development compromises existing levels of flood risk. Conversely, development on the floodplain may still occur, as long as conveyance or flow paths are not jeopardized.

An extensive system of dikes and levees encompasses the tidal zone in the lowlands.

Constraints: Dikes and levees are prevalent in the estuary and tidal lowlands (Figure 7-10). Shaded areas indicate the remaining land areas assumed to be freely exposed to tidal action. These areas represent a small portion of the area designated as the tidal zone (Figure 7-4), which was delineated without consideration for dikes or levees. A comparison of the two areas shows the extent to which dikes and levees have removed high tidal mud flats and marshes from tidal inundation. Since the dikes and levees were primarily designed to prevent saltwater intrusion onto reclaimed pasturelands, they are low in height and vulnerable to overtopping from river flood events. When these structures are overtopped, floodwaters are detained from reaching the bay and pasturelands remain inundated longer that what might occur naturally. The levee systems, which are open to inland river flood flows, are most prone to this condition. This is evident in the Tillamook River and Kilchis River floodplains. Collectively, the levee and dike system forms a constriction to both tidal and river flows, and this likely affects the transport of sediments and the heights and durations of water levels in the lowlands.

Opportunities: The existing dikes and levees offer an excellent opportunity to manage and direct tidal and river flows through the estuarine and tidal reaches of the system. Use of monitoring and computer simulations can help predict salinity intrusion, tidal circulation and flushing characteristics under a variety of restoration scenarios. A wide range of alternatives are possible for managing salinity, inundation duration and water quality, while protecting agricultural interests and improving habitat. In some areas, different levees and dikes along the water bodies are in different jurisdictions, e.g. the City of Tillamook vs. Tillamook County. Therefore, wherever dikes and levees are considered for modification as part of restoration efforts, these jurisdictions should be encouraged to coordinate their open space plan elements with respect to linear parks or open spaces in riparian corridors.

Numerous tide gates and culverts are located in the lowlands that regulate tidal and river flows, and may impede the seasonal migration of salmon.

Constraints: The dispersed locations of culverts and tide gates (Figure 7-11) represents a patchwork of flood control structures that modifies and complicates the natural flow of tidal and stream flows in the lowlands. The elimination of periodic flooding and sediment deposition means that the rate of sea level rise exceeds natural sedimentation rates, such that marshes are gradually inundated - or become mudflats/subtidal if restored. This problem is exacerbated in areas that have been diked and drained for agricultural use. Land protected in this way may subside through compaction and loss of organic matter. This subsidence may accelerate over time, and with use of the land. Subsidence can greatly constrain the success of restoration for tidal wetlands (Frenkel and Morlan, 1991). Over time this can be a problem to farmers as well, as their property gradually becomes lower relative to the ocean levels, and more prone to waterlogging and standing water from rainfall runoff. The freshwater wetlands that result from this ponding are often colonized by soft rush (*Juncus effusus*) and slough sedge (*Carex obnupta*) which are unpalatable to cattle. Multiple ownership of the structures may constrain the ability of a system-wide effort to retrofit or remove these structures to reduce regional flood risk and restore large contiguous areas of habitat. Unforeseen circumstances, such as debris blockages after flood events, may create localized maintenance problems and lead to unintended consequences in the operation of the gates. Tidegated diversion structures or backwaters may also strand fish that have entered and then cannot get out, dying as side channels dry out or getting washed into fields.

Opportunities: Many culverts with fish passage issues are located on streams tributary to the mainstem lowland rivers and outside of the FEMA 100-year floodplain. The retrofit of culverts for fish passage often requires extensive permitting and design considerations if insurable structures are located nearby, because changes in the size of a culvert may change flood elevations. The relatively undeveloped state of the agricultural lands may provide opportunities for economical culvert retrofitting with immediate flood risk reduction and fish passage benefits. The large number and distribution of tide gates in the lowlands may provide opportunities for managed flooding and restoration of tidal lands. These locations of existing infrastructure are logical places to modify the original flood control function of the gates for flood management purposes. Several local initiatives have been undertaken to do this, in response to past flood damages and continued flood risk. The majority of these projects are in the estuary/tidal zone, with the exception of the projects located on the Wilson River upstream of Highway 101. The estuary/tidal zone projects are intended to reduce the detention effects of the tidal dike and levee system. Larger tide-gates and dedicated floodways are proposed to increase the drainage of floodwaters as flooding recedes (Jones, 1999). Opportunities exist to build upon these identified projects by expanding or linking them to other projects that will restore full tidal action and lead to the recovery of salmon habitat. Diked-off lands with remnant tidal channels may offer particular opportunities for restoration. This is because the remnant channels may be able to carry restored tidal flow into the site in a natural fashion, or alternatively, they may provide guidelines for excavation work to channel reintroduced tidal flow. Recently altered sites may still have more of the original vegetation (in the seed bank, if not above ground), and may have undergone less subsidence compared to sites altered long ago.

Lowland flood damages have been numerous and repetitive, and have occurred on salmon-bearing rivers and sloughs.

Constraints: Flood damage claims are an indication of human features exposed to flood risk, and repetitive claims underscore the severity of this risk. Figure 7-12 shows locations of FEMA and NRCS flood claims with respect to the lowland and estuary landscape zones. A limited number of damage claims occur in the tidal floodplain zone. Repetitive damage claims are clustered along the Highway 101 corridor as expected, within the 100-year floodplain zone along the Wilson River. However, a higher repetition of claims occurs along Dougherty and Hoquarten Sloughs. No FEMA damage claims are evident further upstream of the Highway 101 corridor in the 100-year floodplain zone and active floodplain zone. NRCS road system damages are frequent within the tidal and lowland floodplain zones of the Trask River and along the Southern Pacific Railroad crossing of the Trask and Wilson Rivers. These damages are associated with human features in the floodplain that have been impacted by flooding. Conversely, these features likely impact the natural process of flooding.

Opportunities: There is an opportunity to reduce the economic and social costs of flood damages by understanding where, and how frequently, damages occur. Segments of the river system near damage claim locations should be prioritized for evaluation of the cause of damages. The objective would be to formulate flood response plans that incorporate alternative emergency actions aimed at reducing future flood risks and restoring natural floodplain processes and habitat. In addition, FEMA has implemented a policy to discourage repetitive claims for properties that have experienced damages from multiple events. Future development in the County should be concentrated outside of the floodplain. Implementation of such a policy could be aided by creation of incentives among multiple jurisdictions such as the County and the City.

An extensive amount of lowland floodplain vegetation has been converted to agricultural lands, but relatively large contiguous wetlands exist in tidal portions of the lowlands.

Constraints: Figure 7-13 shows the location and extent of wetland plant communities as indicated on the National Wetland Inventory (NWI) maps for the Tillamook lowlands. Palustrine wetlands, or wetlands that are temporarily flooded, are concentrated in the tidal portions of the lowland valley and in sporadic locations along the mainstem river channels. The lack of existing wetland communities along the mainstem rivers may constrain the incentives and ability to restore floodplains in the fluvial portions of the lowlands. Many streams and sloughs in the Tillamook lowlands have been straightened and channelized in order to drain the land and improve pasture and farmland. Once a stream has been ditched and straightened, land use and ownership patterns make it nearly impossible to re-establish a meandering channel across a large area.

Opportunities: Large areas of intact wetland plant communities exist in the tidal portions of the lowlands. The brackish-to-freshwater reaches of the marshes, sloughs and rivers present habitat opportunities for salmonids including osmotic transition, a highly productive foraging environment (NOAA, 1990) and deep channels for predator avoidance (Lebovitz, 1992). Tidal forest is still found in very limited areas of the lowlands. The largest remaining area is the forest surrounding Hoquarten Slough within the Urban Growth Boundary of the City of Tillamook (Wilson et al, 1997, and Brophy, 1999b). Other areas are found in upper Squeedunk Slough, and near the mouth of Hall Slough. All of these areas provide opportunities for protection. In addition to their meandering channels, Hoquarten Slough and Dougherty Slough provide habitat for anadromous fish. Additional value comes from their landscape position. These sloughs are located in areas of major flood concern, and they extend far enough up the valley that they provide extensive opportunities for hydrologic restoration. Habitat value may also be gained from straight ditches and channels with terracing, vegetation and the reintroduction of tidal action.

These spatial constraints and opportunities to an IRMS in the lowlands are summarized in a schematic diagram of the natural zones of the river system (Figure 7-14) and a diagram of the primary human interventions in the system (Figure 7-15). The figures illustrate the increasing complexity of natural processes and land use in the lowland river system as the single river channels in the active floodplain zone transition into multiple fluvial and tidal channels within the floodplain.

7.4 Public Policy Constraints and Opportunities

Institutional constraints and opportunities in the management of the lowland valley floodplains were evaluated based on an assessment of the existing public policy concept. The evaluation generally consisted of a review and analysis of flood response permit activities, tools and techniques for policy implementation and enforcement, and policy frameworks. Since a key finding is that public policy activities are not spatially-oriented, this section is not presented with maps, but as a narrative with selected schematic diagrams. As with the mapping from the previous section, the narratives support some of the significant conclusions from this study.

Permit Activity Lacks a Cumulative or Interactive Impact Analysis.

Constraint: Fragmentation and complexity of the permitting process is an enormous and well-documented problem. There are numerous examples of policy "disconnect." For example, joint permit DSL/COE applications may occur where the COE can be cut out of the review process if a fish waiver is claimed. The most prevalent forms of these permits pertain to fill and dredging. The underlying intent of these permits does not correspond to the primary concerns of an IRMS (habitat restoration, water quality and quantity, fish passage, flood hazard reduction) and, consequently, cumulative impacts on the function of the river system can be significant. Permit review and compliance are based on internal review criteria rather than on a cumulative environmental impacts assessment of the individual permit activity or the interactive impacts of multiple permits issued within any watershed. In order to evaluate activity in the Tillamook Bay Basin, the 187 permits issued in 1997 were mapped by sub-watershed, and are summarized in Table 7-2. It should be noted that multiple permits are often issued for a single property, so while the total number may be high, it does not necessarily give an accurate overview of the extent of the disturbance to the habitat. In granting the permits, cumulative impacts of the 187 actions were not evaluated by the various agencies.

Table 7-2 Post Flood Permits Issued in 1997 (multiple permits can be issued for one location)

Tillamook Bay River System Permits

	DSL	NRCS	COE	FEMA	TOTAL
Tillamook	21	4	4	13	42
Trask	31	4	4	15	54
Wilson	22	3	7	10	42
Kilchis	14	2	2	2	20
Miami	15	1	3	10	29
TOTAL	**103**	**14**	**20**	**50**	**187**

Opportunity. Two existing vehicles could be adapted to facilitate integrated planning and assessment. The NEPA framework, together with the OWEB Watershed Assessment Manual, provide a structure to define baseline resource and ecosystem conditions, and to evaluate implications of actions in relation to development standards and environmental impact. The cumulative impact analysis component of NEPA can be used to correlate actions with the three main ESA concerns (flow rates, water quality and habitat) and to define impacts on thresholds as specified by Oregon Plan benchmarks. As a preliminary idea, targets would include elements addressed in cumulative analysis:

1. Flow regime: in-stream flow volumes and in-stream flow rates;
2. Water quality: temperature, chemicals, nutrients, sediment load, other;
3. Habitat: a) upper watershed - near shore, forested uplands, riparian corridors, other; b) lower flood plain/near shore - wetlands, riparian corridors; c) in-stream.

Public planning and policy structure is aspatial and/or is not adaptable to spatial correlation.

Constraint: Review of the Oregon Plan benchmarks and the Tillamook Bay CCMP reveals little relationship to existing spatially-defined policies and relations that regulate land use actions. The Oregon Plan is aspatial because benchmarks have been defined by agency mandates rather than spatial limits or jurisdictions. Furthermore, under the plan each agency is directed to goals with respect to fish recovery in each river. It should be noted that benchmarks have not been translated into specific local agency strategies.

Opportunity: A strategy is needed to strengthen the capacity of existing bodies such as the watershed councils to achieve interagency coordination (state, federal and local). Considering that each jurisdiction is required to adopt a comprehensive plan, and that administrative guidelines exist for implementing Goal 5 (natural resources, science and historic areas, and open spaces), it is assumed that a strong framework now exists for implementation of the Oregon Plan targets. The Oregon Plan increases responsibility and accountability at the local level. The issue at this point is to translate accountability (including benchmarks) into the spatial dimensions of a multi objective IRMS.

There is a need to specify spatial information in a format that can be used to refine the implementation framework to achieve flood hazard reductions and habitat restoration. The difficulty of correlating regulatory requirements with ecological regimes is illustrated in Figure 7-15. Landscape features based on an ecological regime have been identified by other components of this project. In order to translate them into existing regulatory tools, the categories must initially be correlated with the existing regulatory context. An example of this is shown in Table 7-3.

Table 7-3
Correlation of Landscape Features to Existing Regulatory Tools

Landscape Features	Existing Regulatory Tools
Watershed	watershed councils; counties
Shorelands	200 feet from higher high tide or top of bank and Goal 17
Estuaries	Goal 16 Coastal Zone Management
Riparian Corridors	75 from top of bank, Goal 5
Wetlands	404 COE and DSL, Goal 5 and County
In stream	402 review

Existing GIS data sets often do not facilitate policy analysis because base data is difficult to correlate spatially.

Constraint: From a review and evaluation of the GIS data used in this project, it was apparent that the data do not necessarily support planning or regulatory needs. For example, because of a lack of spatial definition, it is impossible to correlate critical cultural features (such as legally mandated riparian corridors, shorelands, and zoning boundaries) with ecological and geomorphological features such as riparian habitat.

Extensive data is available regarding permit activity; however, a lack of precision in activity location makes interpretation difficult. For example, attribute data were not available for the 187 permits reviewed, and permit purpose was therefore unclear, e.g. whether a given permit was issued as part of a flood response or a land use action.

A lack of metadata associated with data points can lead to erroneous conclusions. For example, permits issued for the same action appeared at different locations on the map because of differing location tracking systems. The FEMA data appears to be based on damage survey reports for public facility repair from the 1996 flood. The data incorporate a large number of actions including debris removal and roadway and culvert repair, and do not necessarily reflect activity types comparable to the DSL data points.

Another problem occurs with the overlaying of point data onto polygon map data. Using the FEMA data set correlated with land ownership, represented by large polygons, results in erroneous conclusions because the public vector data (roadways) and spotty parcels of public ownership have not been included. For example, DSL permit location data, available by section, township and range, are represented as raster data, while features such as rivers are vector data. Thus, important policy issues such as number of permits issued within the regulatory riparian corridor are impossible to show. Although the resulting map is helpful for estimating the approximate number of permits, it does not give an accurate idea of where these permits were located.

Opportunity: A case study utilizing GIS or new three-dimensional imaging techniques could be applied to one basin, such as the Wilson or Trask, to present a 2D or 3D view of problems and cumulative impacts. The case study could illustrate hydrologic concerns for the rivers and then project the implications of alternative actions.

There is a lack of a multi-objective policy framework.

Constraint: Flood hazard reduction efforts administered by the COE and FEMA (diking practices, zero net rise in Base Flood Elevations) are often solely based on hydraulic criteria and can be in conflict with habitat restoration and other ESA related issues that are based on biological and geomorphic criteria. The discrepancies in mission are compared for three key types of issues in Table 7-4.

Table 7-4 Prototype Issues: Comparison of Flood Hazard Reduction with Salmon Habitat Restoration Perspectives

Prototype Issues	Flood Hazard Reduction	Restoration Perspectives	Remarks
Stream Channel and Habitat Assessments	Minimize opportunity for water level rise i.e. minimize encroachment into the use of channel	Maximize salmon resting places i.e. through placement of LWD	Conflicting priorities
Uses in the flood plain	Minimize risk of property to damage; insurance exposure	Minimize wetland and riparian habitat conversion	No convergence of issues
Stream Biotic Condition and Ambient Water Quality	Minimize erosion and excess sedimentation	Assess impacts of diversion on water temperature and on flow, etc.	No convergence

Multi-objective management is difficult for agencies to address within their statutory and organizational mandates. Regulations and programs of individual agencies have been established to meet specific mandates, which are typically single-objective and task oriented. For example, the NRCS uses the floodplain as defined from a geomorphic standpoint--a critical concept for habitat restoration. This differs from the regulatory floodplain definition under FEMA's NFIP, which is a statistical construction (1% annual chance of flooding) and adopted as part of a participating community's comprehensive plan. This makes it difficult for property owners and communities to establish clear and consistent policies. Figure 7-16 compares the regulatory with the geomorphic floodplain.

Opportunity: The complex mission of an IRMS is to balance ESA objectives with flood hazard reduction objectives. Increasingly, funding of flood restoration has emphasized multi-objective projects under its competitive grant programs. These grants are available to help communities reduce the effects of flooding, while also improving habitat for threatened and endangered species. In addition, the Oregon Plan is requiring a multi-objective process. The IRMS is inherently multi-objective because it advocates:

1. the restoration of floodplain functionality,
2. the reduction of flood impacts;
3. the improvement of aquatic and terrestrial habitat.

Local governments are required to develop a program to achieve Goal 5 for all significant resource sites through the adoption of comprehensive plan provisions and land use regulations. Goal 5 resources include water areas, fish habitat, adjacent areas, and wetlands within the riparian boundary. It therefore represents an ideal vehicle to implement the multi-objective IRMS approach. The strategy to comply with Goal 5 would consist of four steps:

1. Identify conflicting uses;
2. Determine the impact area;
3. Analyze the economic, social , environmental, and energy (ESEE) consequences that could result from a decision to allow, limit, or prohibit a conflicting use;
4. Develop a program to achieve Goal 5.

It should be noted that according to the Goal 5 administrative rule, "the riparian corridor boundary is an imaginary line measured upland from the top of bank. The local governments may determine the boundaries of significant riparian corridors using a standard setback distance form all fish-bearing lakes and streams … as follows:

1. Along all streams with average annual stream flow greater than 1,000 cfs, the riparian corridor boundary shall be 75 feet upland from the top of each bank.
2. Along all lakes and fish-bearing streams with average annual stream flow less than 1000 cfs, the riparian corridor boundary shall be 50 feet from the top of bank.
3. Where the riparian corridor includes …significant wetland…the boundary shall be measured from and include the upland edge of the wetland."

There is a lack of an integrated, comprehensive planning viewpoint.

Constraint: Both flood hazard reduction planning and salmon restoration efforts have emphasized restrictions on property uses within the floodplain. Currently, there is a notable lack of incentive to develop in a manner that conserves and restores habitat. Furthermore, government actions often tend to encourage additional encroachments in the floodplain. One example is the current funding for improvements of the Highway 101 corridor in Tillamook County. The improvements reinforce the conventional wisdom that economic vitality requires extensive parking and pedestrian amenities (sidewalks, covered walkways). These amenities are available to new sites and in conjunction with restoration of damaged structures after flooding. Additional pressures on land owners are caused by restrictions on uses of land in the floodplain, limited land area available for development and economic use, and the existence of virtually no incentive to develop within the existing urban area. In Tillamook, all these factors have created a highly negative attitude among significant segments of the population.

Opportunity: Implementation of creative means to strengthen and increase the drawing power of existing commercial centers located outside of flood-prone areas could be a vehicle to alleviate the ever-increasing development pressures on the floodplain. A prototype concept plan could illustrate the use of incentives that could encourage both prudent floodplain urbanization and implementation of a range of restored habitat environments. This prototype demonstration could explore and apply tools including economic development funding, Smart Growth Initiatives, wetland banking, transfer of development rights, trading credits for provision of additional riparian habitat and other vehicles. Figure 7-17 indicates areas of prototype concern.

Regarding portions of the basin targeted for enhancement, the priority would be to target core areas per OCSRI.:

"'Core areas' are stream reaches (including their connected sub-basins) or watersheds within individual coastal basins that currently support relatively high densities of spawning and/or rearing. Therefore, they are of critical importance to the persistence of salmon populations that inhabit the basin. These reaches or basins have been provisionally identified on maps to provide information that can help prioritize efforts to conserve and restore habitats that support salmon."

A range of strategies and tools could be developed consistent with administrative strategies in Goal 5 and any forthcoming Section 7 guidelines. Cumulative impacts of these measures could be analyzed, either in conjunction with Section 7 consultations, resulting in a prototype HCP, or in conjunction with county efforts. Section 7 of the ESA regulations recognizes that an emergency (e.g. a natural disaster or other calamity) may require expedited consultation (50 CFR 402.05). NMFS has strongly urged the development of a programmatic consultation so that identified adverse effect determinations can be addressed and implemented to protect listed species or critical habitat during emergency actions. This prototype could be integrated into the programmatic Section 7.

7.5 A Future Vision of Lost Opportunities and Increased Constraints

This section provides a possible future vision of the Tillamook Bay river system if an integrated system-based approach is not taken. This view is intended to articulate potential lost opportunities and increasing constraints as time continues and if the river system continues to be managed as it has been. One purpose of this exercise is to establish "no-action" conditions from which to gauge the relative effect of management actions that may be taken within the river system. The following hypothetical considerations of the Tillamook Bay river system summarize potential conditions over the next 100 years if no actions are taken to adapt human activities to natural processes.

7.5.1 The Continued Evolution of the River System

- The physical processes of erosion and sedimentation, orchestrated by climate and streamflow, will continue to exert influences to shape the landscapes and fluvial systems of the Tillamook Bay

Basin. Disturbances such as flooding, drought, landslides, fire and sea level change, occurring naturally or with human inputs, will contribute to the evolution of the river systems of Tillamook Bay by altering the structure and function of these systems.

■ Climate change and its effects on sea level change will play an increasing role in shaping the future estuarine landscapes along the margins of Tillamook Bay. Sea-level rise, coupled with subsidence of the land mass in the Tillamook area, results in the area being submerged at an estimated rate of about 2 millimeters per year, or 8 inches in 100 years.

■ For dikes encompassing the Stillwell Drainage District, this elevation change would reduce by nearly half the original 2-foot freeboard design criteria for the 50-year flood event (U.S. Army Corps of Engineers, 1956). The rise in sea level would raise the Mean High Water tidal datum to the elevation of the current Mean Higher High Water datum and cause the limits of tidal marsh vegetation to recede to the new MHHW datum. For a typical intertidal mudflat slope in Tillamook Bay of one foot vertical to 250 feet horizontal, this implies marsh vegetation could retreat inland up to 170 feet.

■ Recent investigations of sediment accumulation in the bay indicate an average rate of 5 centimeters per century, with these deposits occurring primarily along the margins of the bay (McManus et al., 1998). As such, the river deltas are extending into the bay, lengthening the lower reaches of confined river channels and flattening river slopes. The gentler river gradients and longer reach lengths would reduce the energy available in the river flows to transport sediments. This condition, combined with higher tidal elevations imposed by sea level rise, would lead to increased channel deposition in the tidally influenced reaches of the rivers.

■ Flood control improvement projects constructed in the estuary will provide increasingly fewer benefits over time, because the relative rise in sea level was not accounted for in the original design of this infrastructure. In addition, a lack of management actions in the uplands will lead to excessive volumes of water and sediment transported to the lowlands, invalidating the original design criteria. Maintenance costs will skyrocket and retrofits will be necessary to maintain the function of the structures.

■ The characteristics of the Tillamook Bay lowland valley 100 years from now may be drastically changed if a major subduction zone earthquake were to occur within this time frame. The estimated maximum subsidence from past earthquakes along the northern Oregon coast is one meter, based on paleosubsidence records. Rapid subsidence of this magnitude in the Tillamook Bay area could lead to drastic changes in hydraulic and geomorphic processes. The ensuing adjustments of the river systems to these tectonic changes would extend over a significant time period and require short- and long-term adjustments to human infrastructure and cultural conditions.

7.5.2 Flood event and flood damage trends

■ After a lull in severe flood events through the late 1970s and 1980s, the Tillamook Bay area, and communities throughout Oregon, have recently experienced significant repetitive flood events. Flood events may continue to be more pronounced in the Pacific Northwest during the next 100 years. Climate researchers have predicted a trend toward warmer winters as a result of global warming (Long, 1998). With warmer winter temperatures there is an increased chance for winter rain and rain-on-snow flood events. This anticipated trend in climatic conditions, coupled with the plan for renewed harvest of timber from the Tillamook State Forest, may lead to changes in flood damage trends in the lowland valleys of Tillamook Bay.

■ The significance of recent and future flooding and flood damages is, in part, due to the increased development of floodplain lands that has placed human property in harm's way. This is especially true in Tillamook, where buildout along the Highway 101 commercial corridor has progressed dramatically. If buildout continues in this low-lying area north of the City of Tillamook, more commercial property will be at risk from flood damage. Sewerage and hazardous materials associated with this development may be exposed to flood waters and discharged into swollen rivers, increasing environmental and human health risk. Since the dikes and levees along riverbanks represent unnatural features on the lowland valley landscape, the forces of weathering and erosion from seasonal climate conditions and flooding will continue to necessitate maintainance and repair of these features by landowners. The deposition of sediments in the river channels will be exacerbated by dikes and levees along the riverbanks which prevent sediment deposition on floodplain lands during flood events.

▪ Public safety and rescue operations will become more prevalent during flood events. Increasing numbers of people will be stranded in homes, motels and businesses designed to be elevated above the 100-year flood, separated by transportation routes severed by quickly rising floodwaters.

▪ Many of the habitat improvement projects designed and implemented without consideration for the overall river system have been damaged or completely washed out by the excessive force of floodwaters constrained between dikes and levees.

▪ Increasing amounts of earth fill placed in the floodplain, to raise cowpads, new bridge approaches, elevated homes and new development above the 100-year floodplain, have further obstructed the flow of floodwaters in the lowlands. These obstructions have increased flood heights and erosion during subsequent flooding.

7.5.3 Flood hazard mitigation efforts

▪ If flood hazard mitigation efforts in the county continue to emphasize the elevation and "flood-proofing" of existing flood-prone structures, and the construction of new structures on fill material to elevations above the published 100-year base flood elevation, the success and cumulative effects of these efforts is uncertain. These mitigation projects, while pursued with good intentions, have major limitations to their effectiveness, because of their underlying reliance on 30-year-old statistical flood data, and because they are implemented without the benefit of a comprehensive flood management plan.

▪ The use of old flood elevation data from the 1977 FEMA flood insurance study to design new flood hazard mitigation measures would impart uncertainity to the success of the measures, because the statistical value of the 30-year-old 100-year flood estimate, and the associated flood elevations, may have changed in the intervening time period, especially given the significant flood events in 1996 and 1998.

▪ The reliance on "flood-proofing" and building elevation as mitigation measures would probably decrease, but not eliminate, risk to commercial and residential property owners. With the next severe flood, raised homes may remain dry and insurable contents protected, yet the inhabitants would be surrounded by flood waters and isolated if they choose to remain on their property. The potential need for rescue and medical emergency services in these situations would continue to place demands on local governments that could otherwise be directed to other aspects of flood response and recovery.

▪ Continued development in the floodplain, insofar as it includes new commercial property on raised earthen foundations and elevated cow pads, will provide some measure of protection against flood hazards. However, the cumulative effect of this filling in the floodplain will reduce the natural storage capability of floodplains and may lead to higher flood elevations upstream of these obstructions. As a flood wave passes downstream, flood flow velocities are concentrated along the edges of floodplain fill, submerged structures and other obstructions, resulting in increased chances for localized erosion and scour at these encroachments. Erosion impacts may be further increased if a flood wave coincides in time with an outgoing tide.

- If Oregon coastal salmon populations continue to decline, the federal government and the state will receive increased pressure from the public to enforce the ESA and CWA. In Tillamook, pressure will also come from the shellfish and commercial fishing industries. These groups will have to watch their livelihoods diminish as the estuary receives an increasing amount of toxic pollutants from urban runoff and flood washoff.

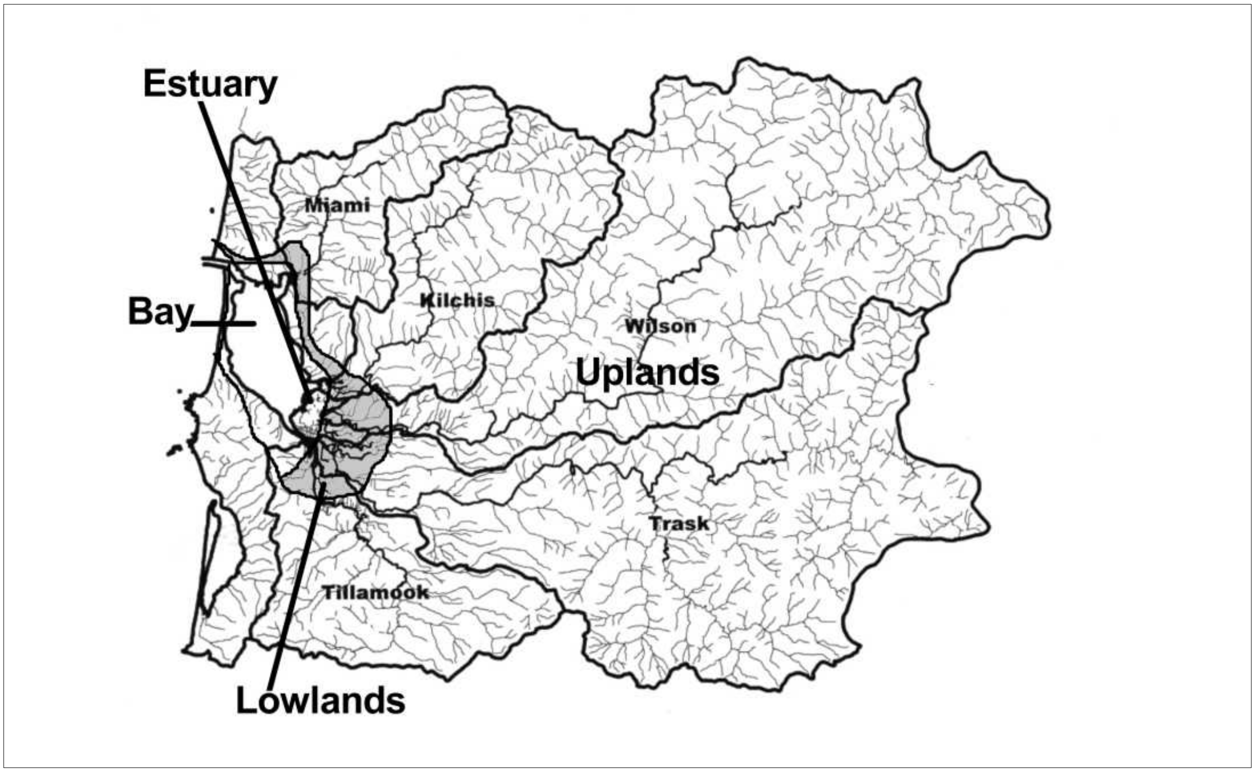

Figure 7-1. General Physical Features of the Tilamook Basin

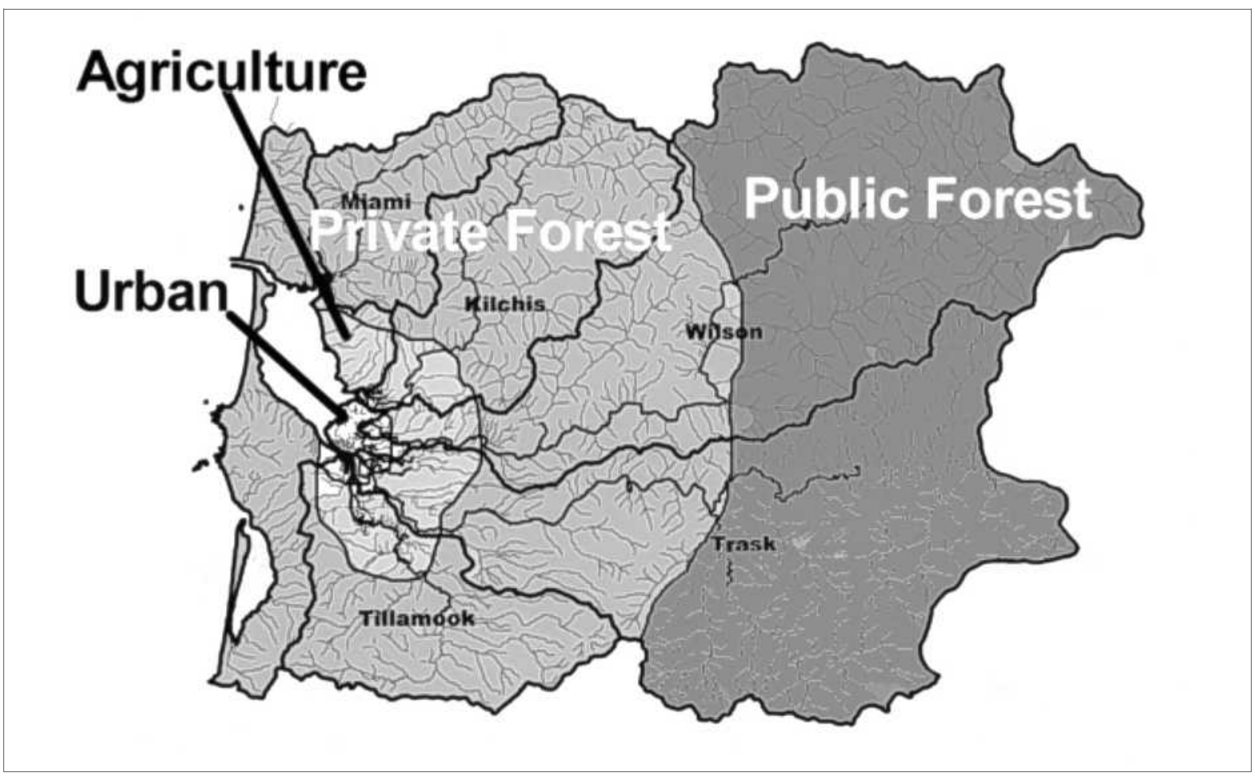

Figure 7-2. Generalized Land Use in the Tillamook Bay Basin

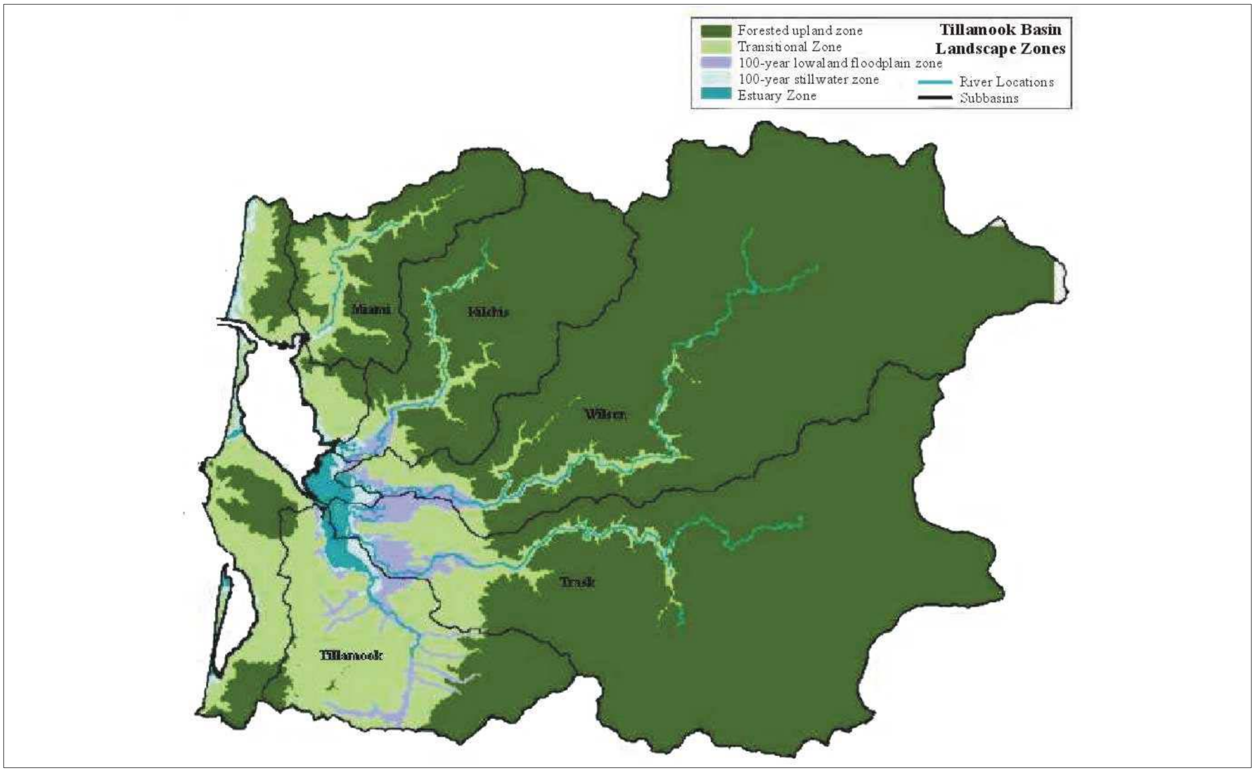

Figure 7-3. Tillamook Basin Landscape Zones

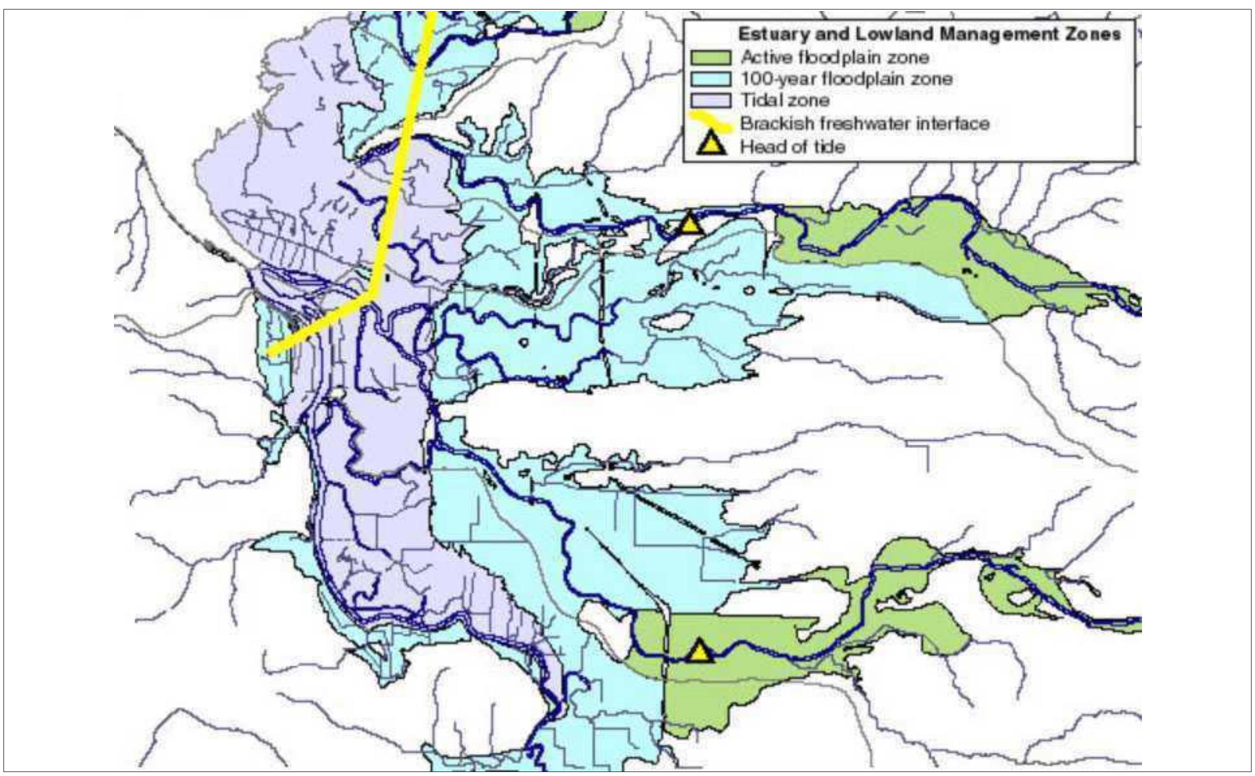

Figure 7-4. Tillamook Lowland Landscape Zones

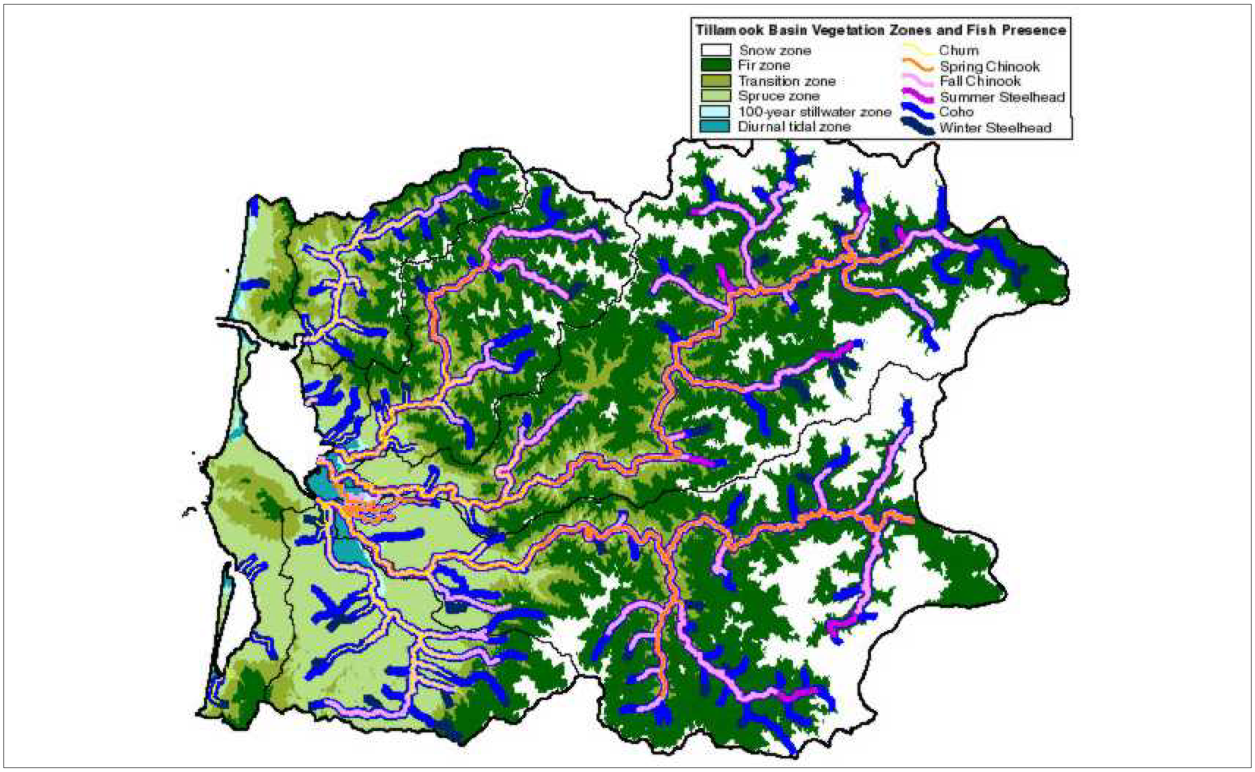

Figure 7-5. Tillamook Basin Vegetation Zones and Salmon Distribution

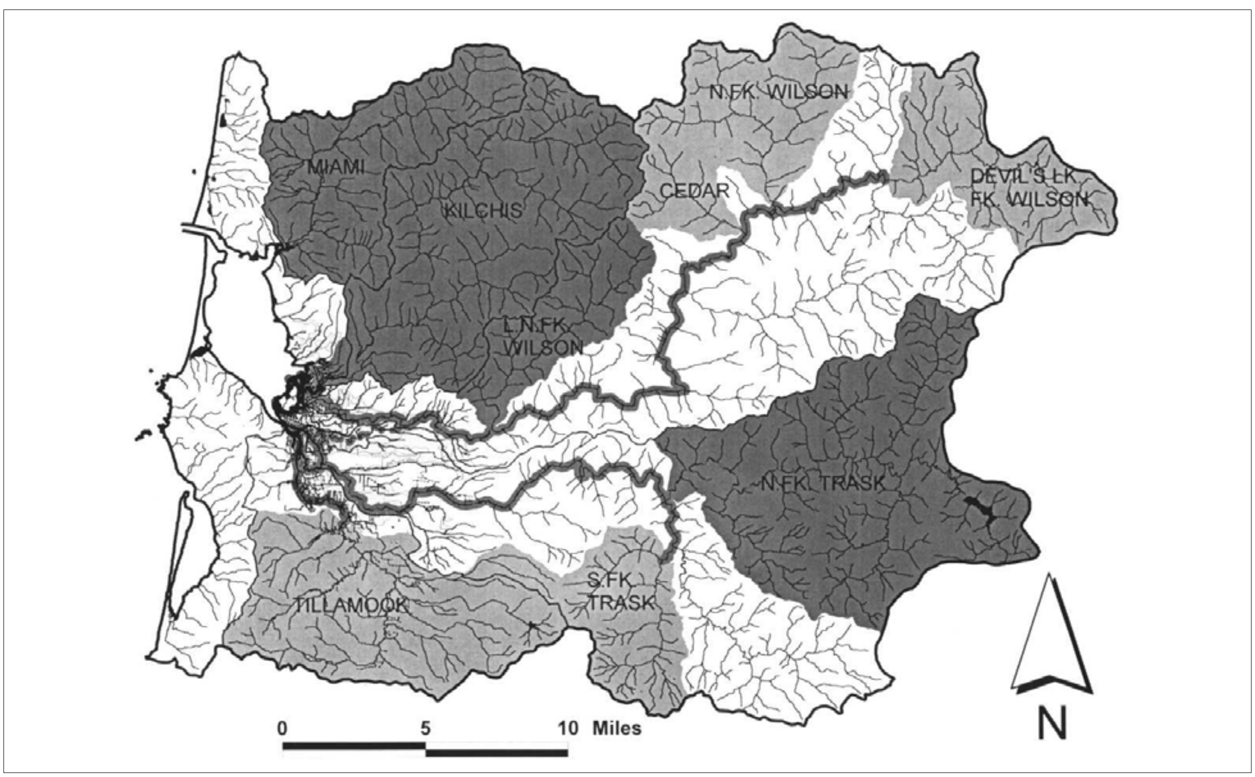

Figure 7-6. Tillamook Basin Salmon Conservation Priority Watersheds

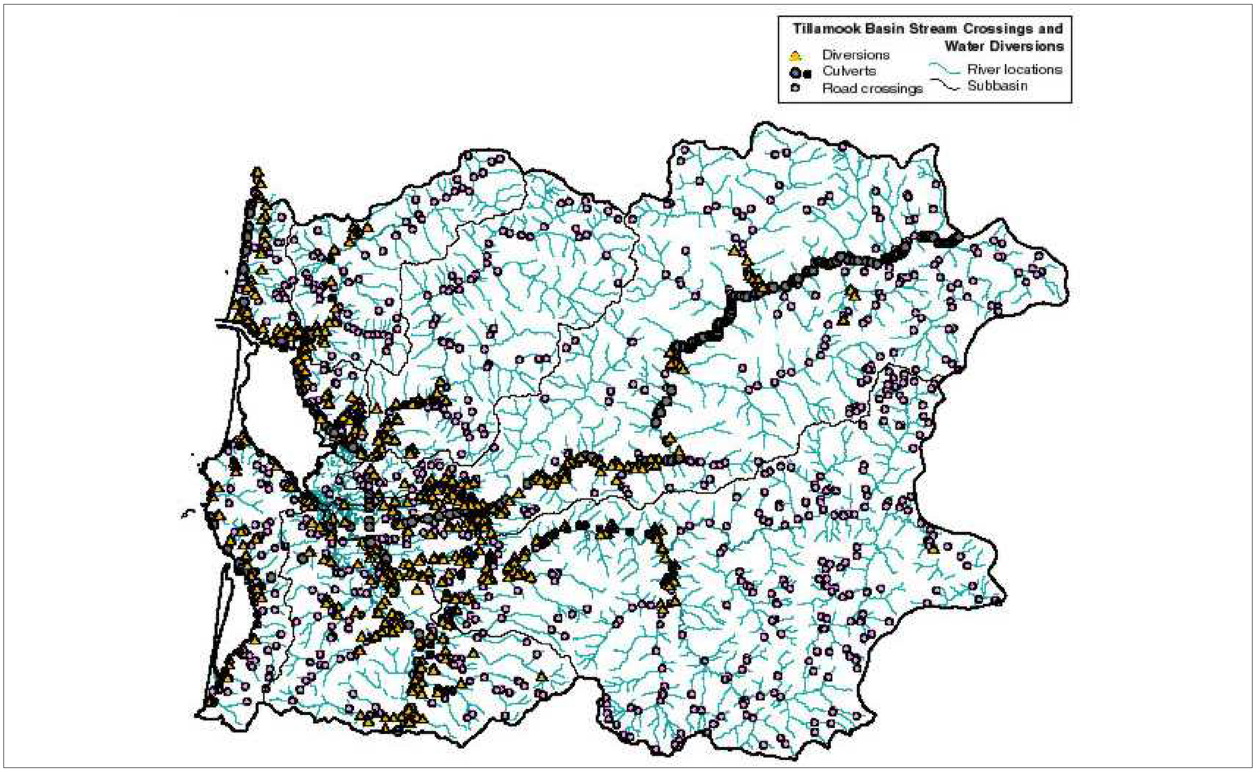

Figure 7-7. Tillamook Basin Stream Crossings and Water Diversions

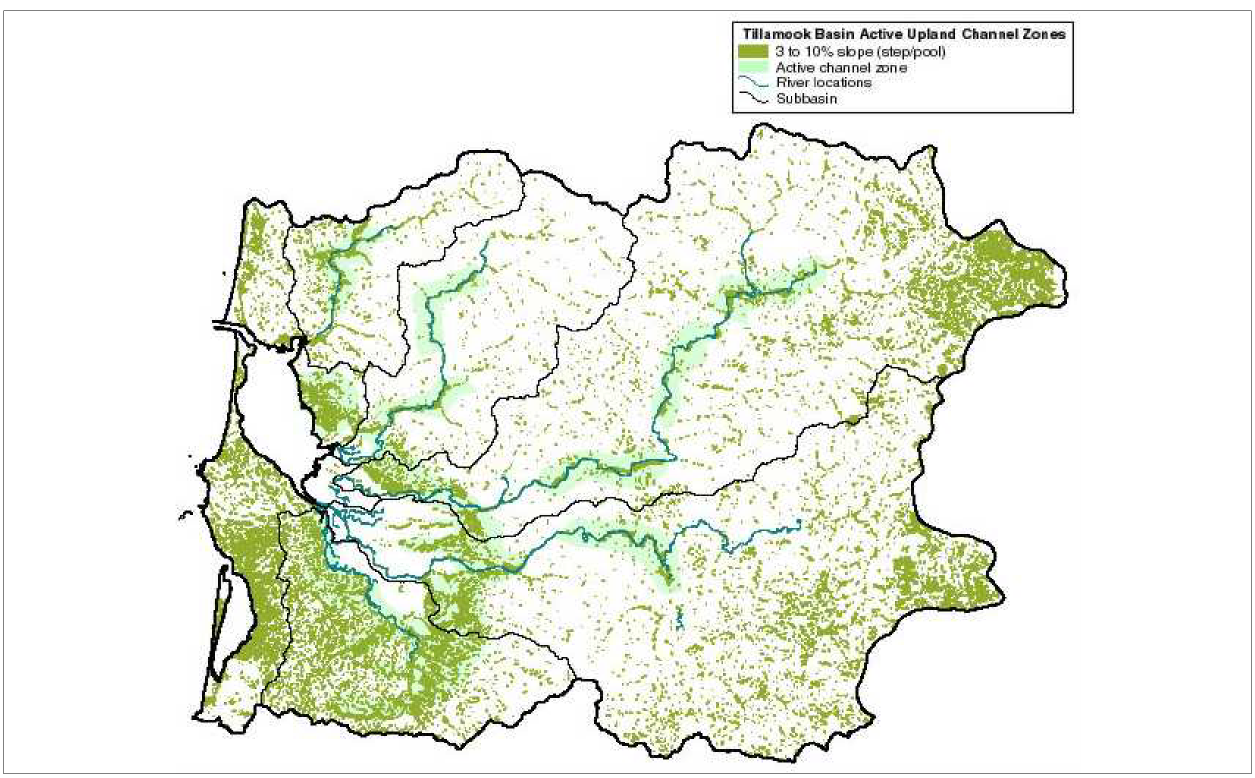

Figure 7-8. Tillamook Basin Generalized Step-Pool Channel Morphology

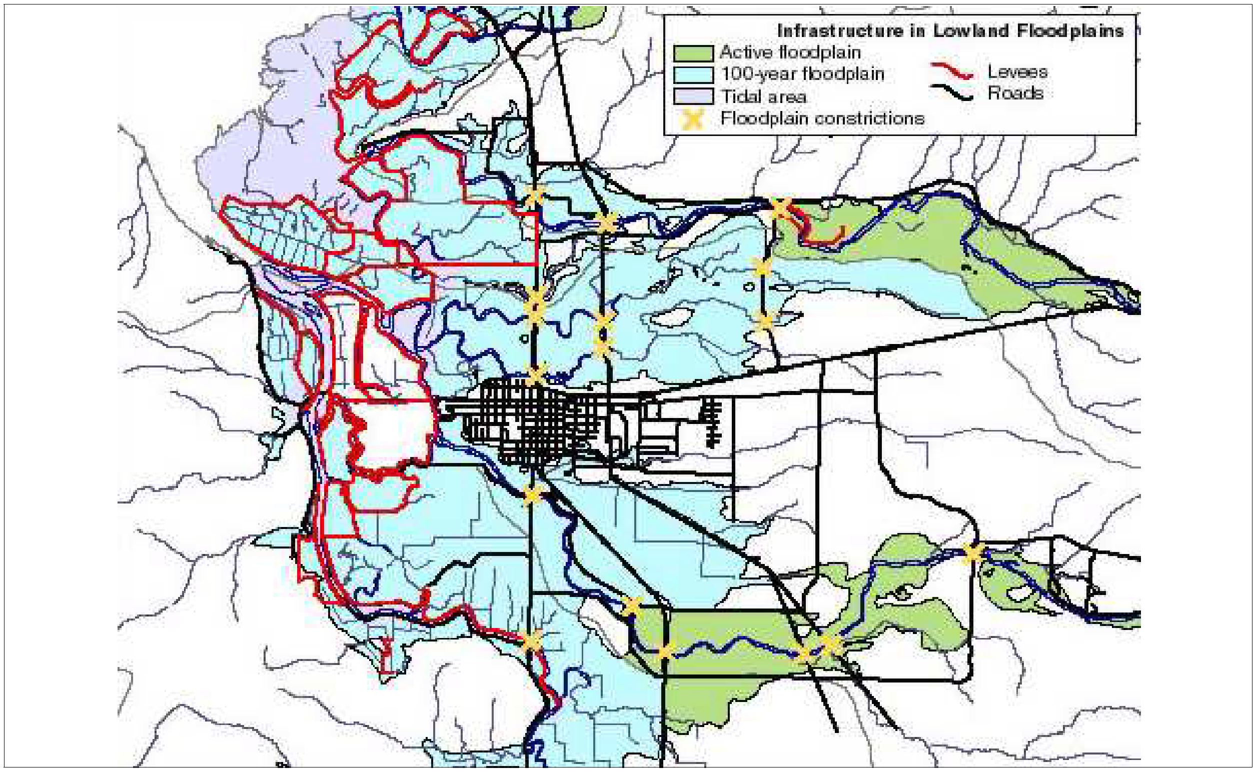

Figure 7-9. Tillamook Lowland Infrastucture

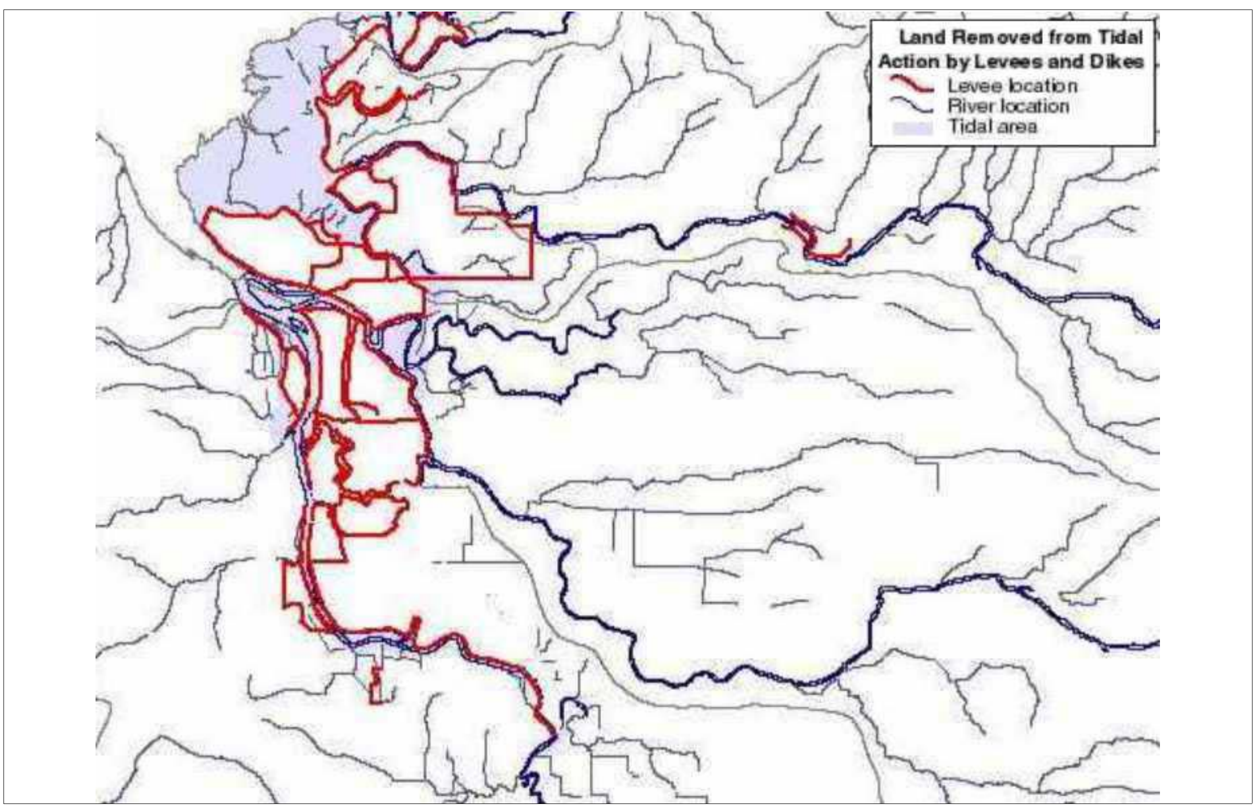

Figure 7-10. Tillamook Lowland Dikes and Levees

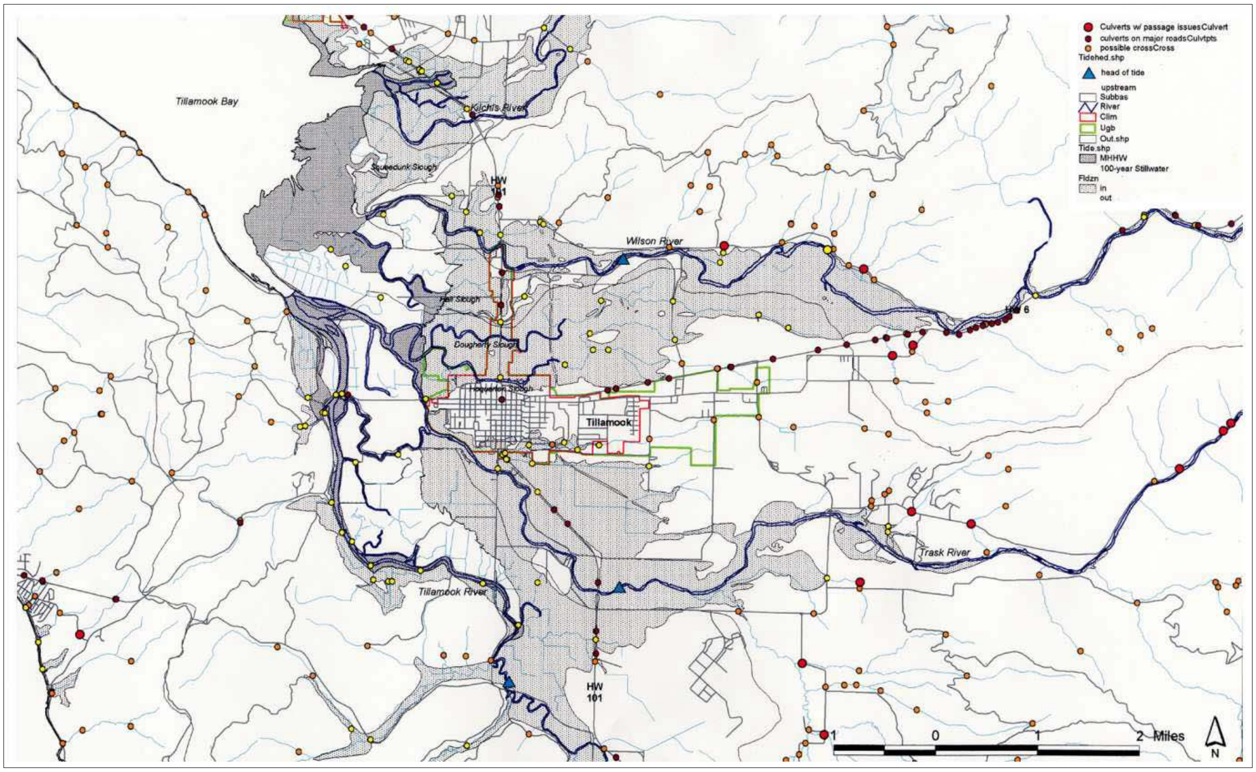

Figure 7-11. Tillamook Lowland Culvert and Tide Gate Locations

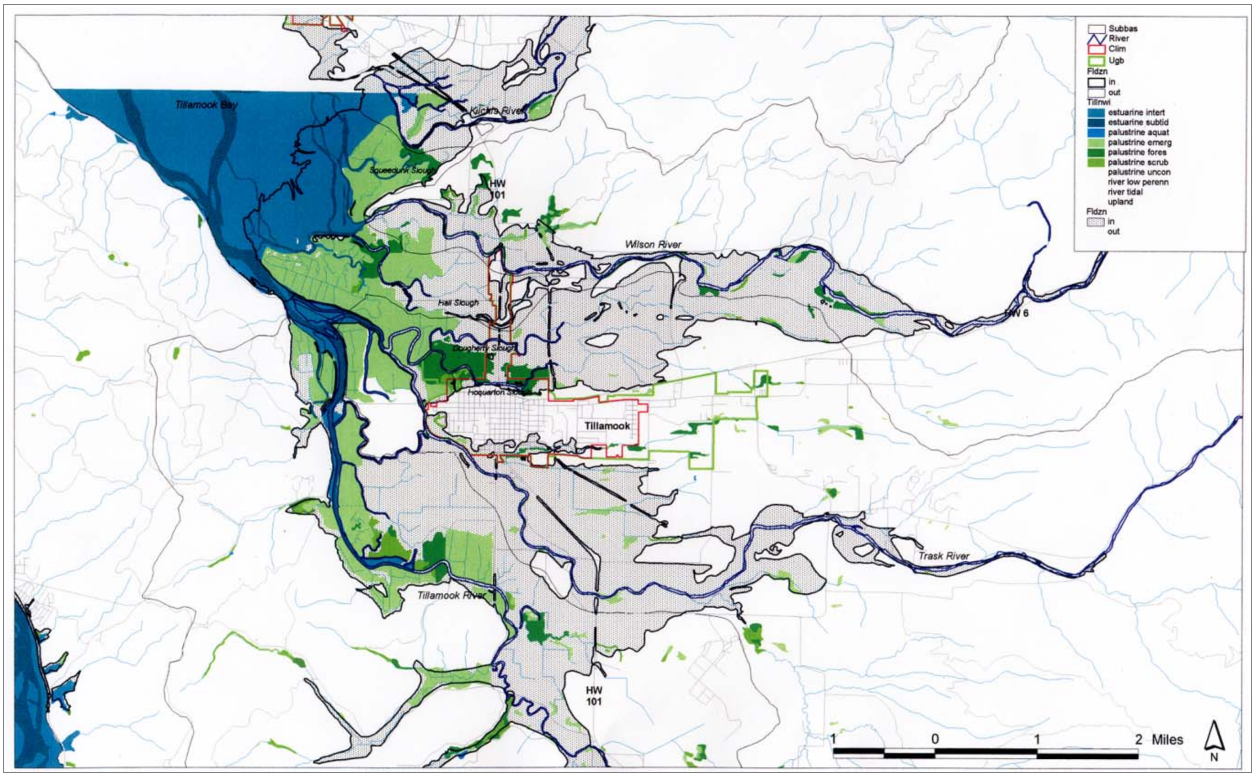

Figure 7-13. Tillamook Lowland Wetland Plant Communities

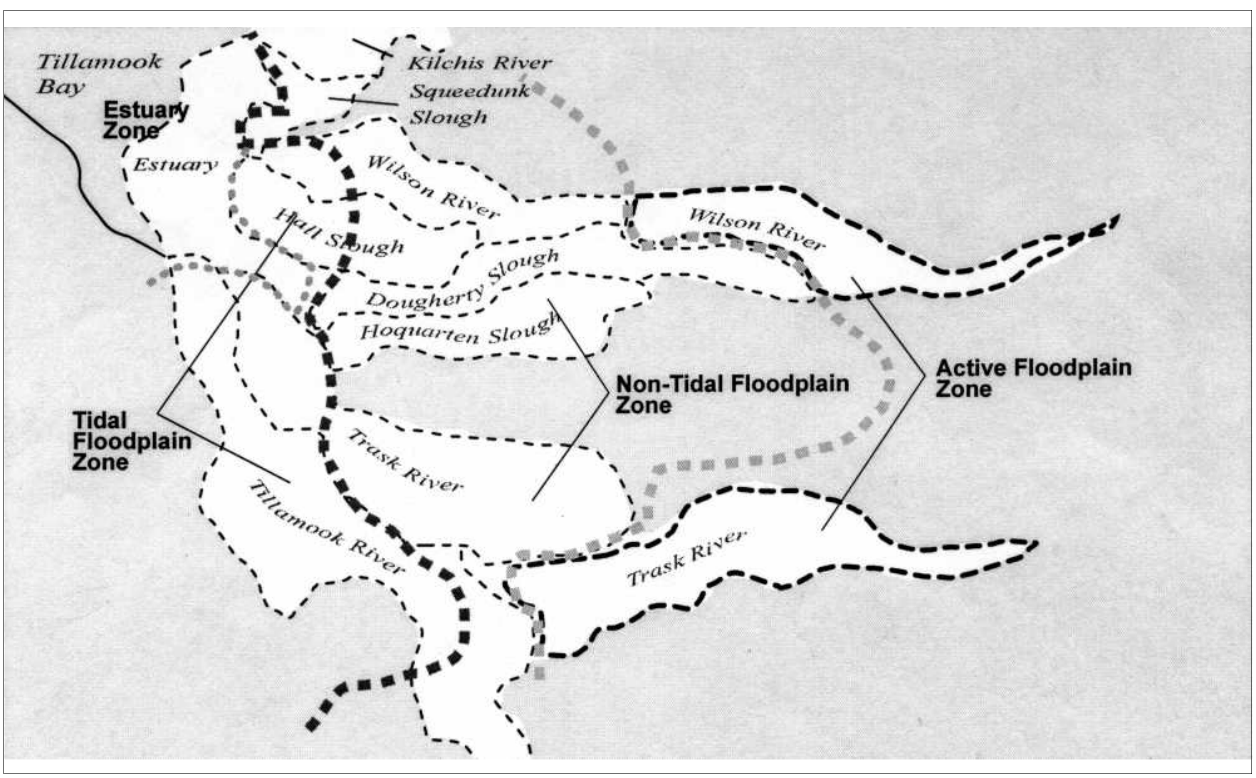

Figure 7-14. Schematic Diagram of Estuary Floodplain Interventions

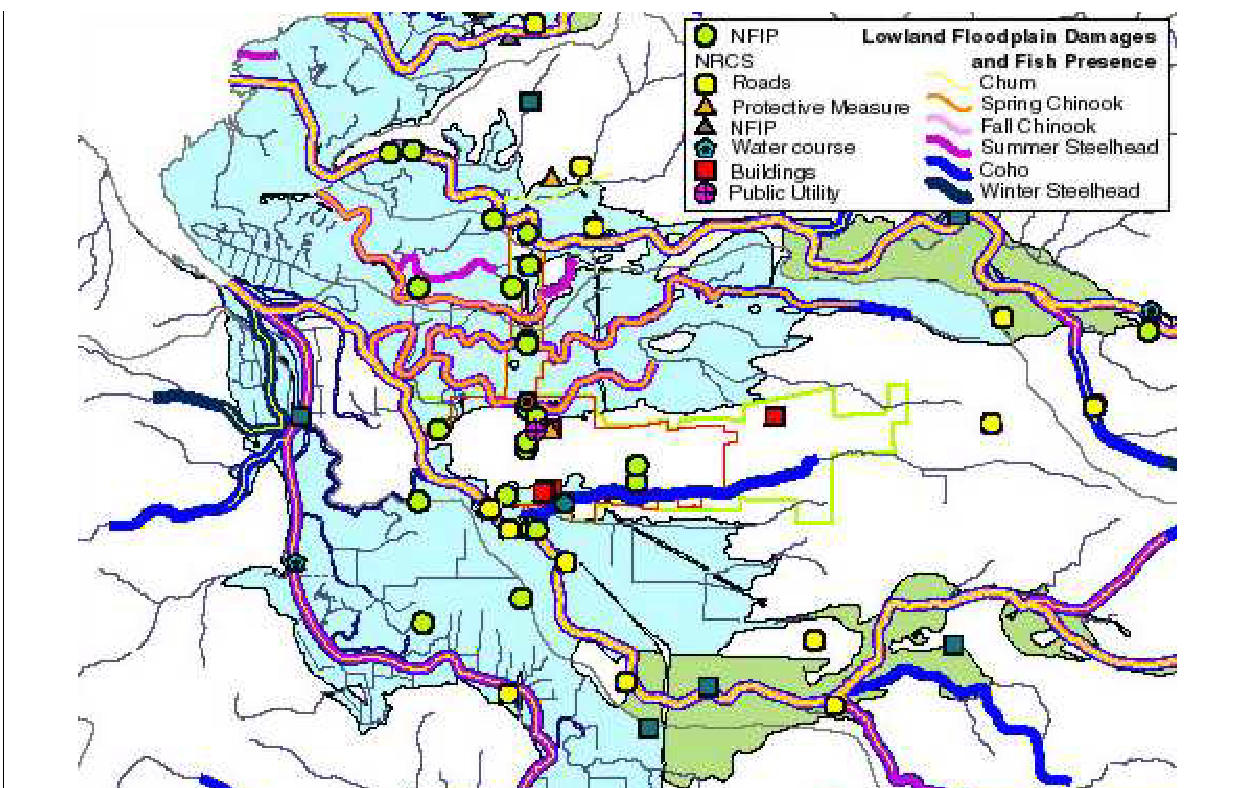

Figure 7-12. Tillamook Lowland Flood Damages and Salmon Distributions

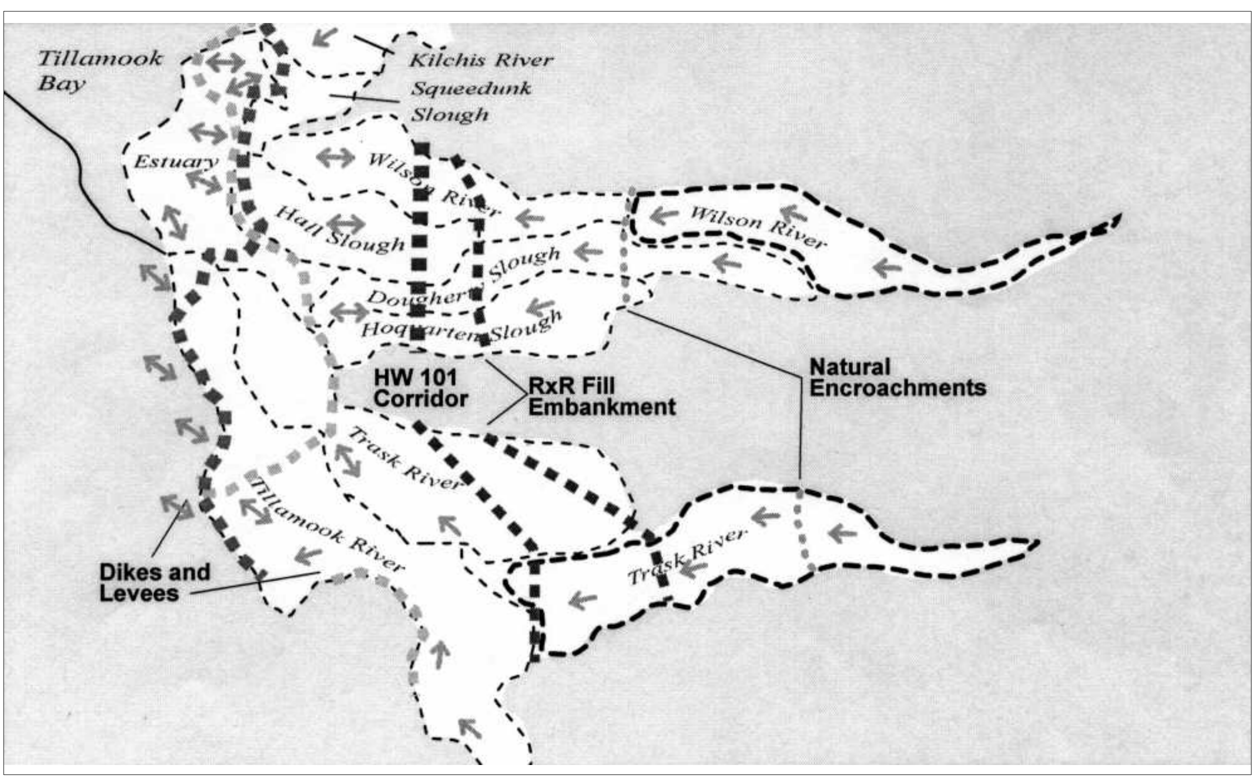

Figure 7-15. Schematic Diagram of lowland Floodplain Interventions

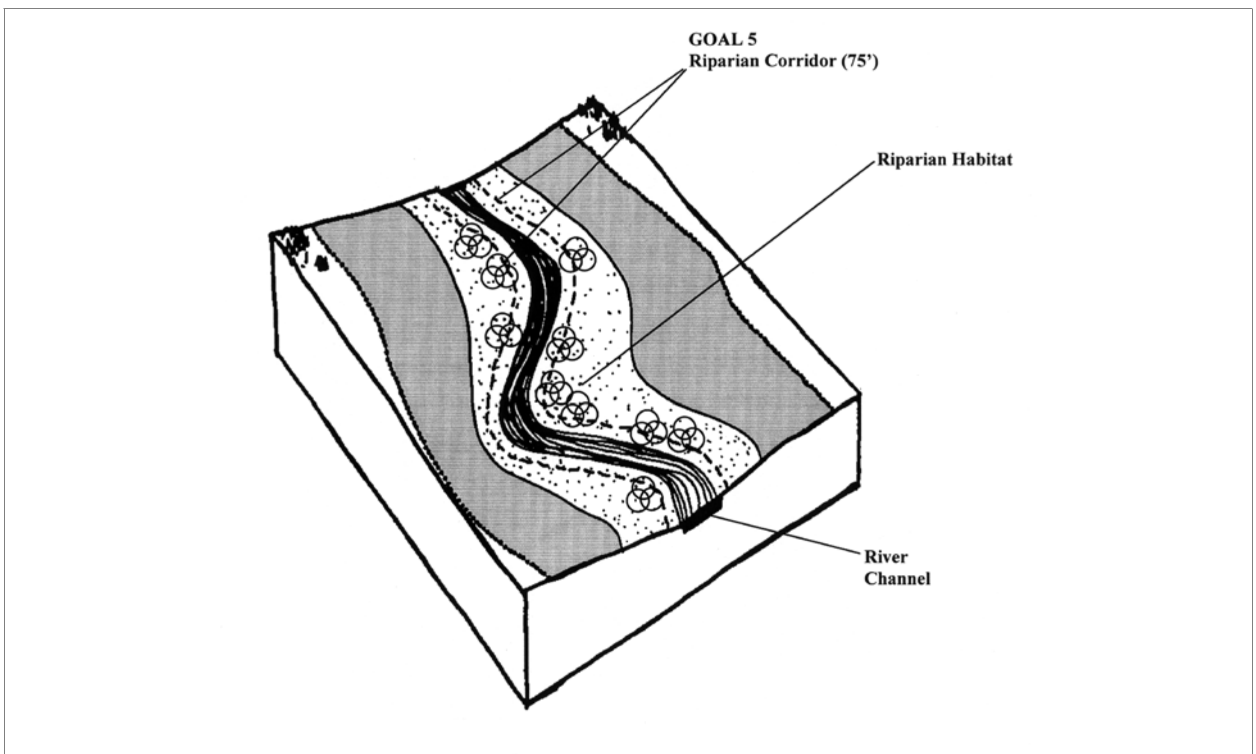

Figure 7-16. Comparison of Regulatory and Natural Aspects of Riparian Corridors

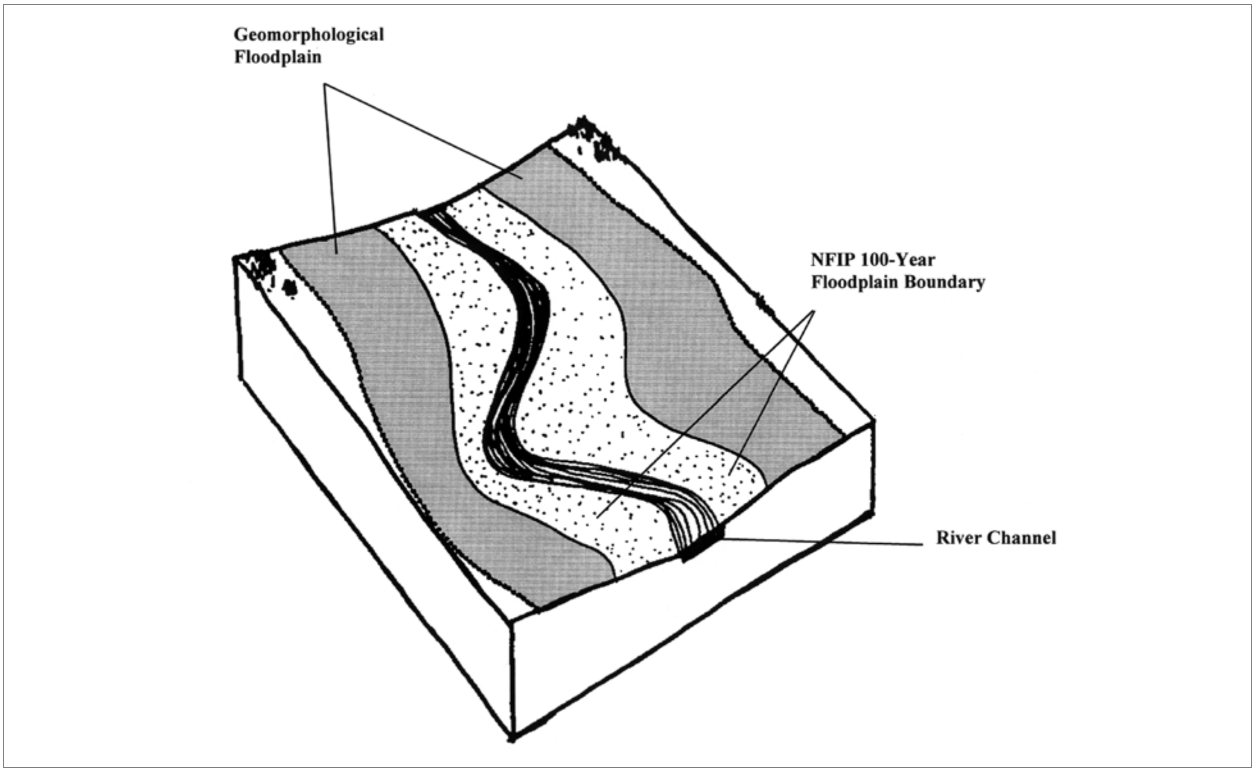

Figure 7-17. Comparison of Regulatory and Natural Aspects of Floodplains

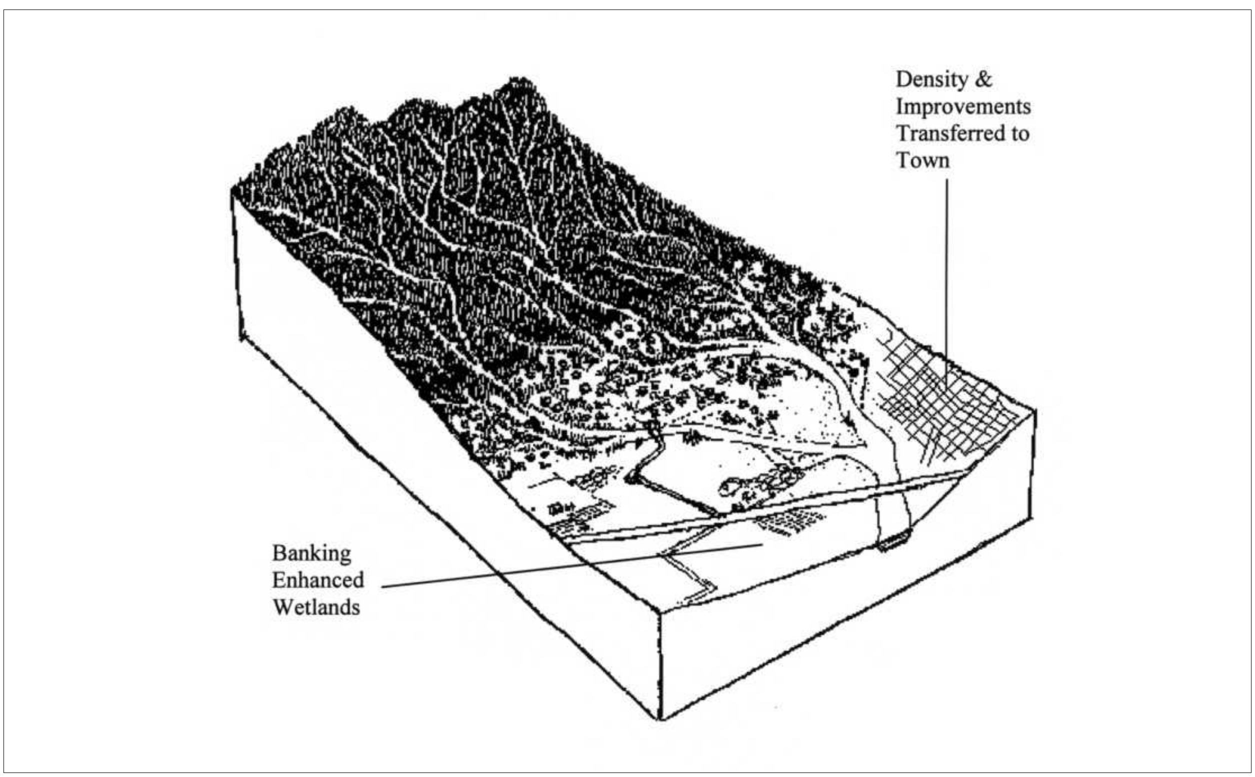

Figure 7-18. Land Use Transfer Concept

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8. An Integrated River Management Strategy (IRMS) for the Tillamook Bay Watershed

8.1 Introduction

This section describes the approach used to develop a planning-level IRMS for the Tillamook Bay river system and the major provisions of the strategy. The IRMS is based upon a holistic approach that considers physical processes at the watershed and local scales, land use and ecological resources of the watershed. The plan is intended as a template that can be refined as additional data and more knowledge on the linkages between physical process and the ecology become available. Adaptive management principles can be used to refine the implementation stages. Planning-level means the strategy is displayed graphically on maps and is based on scientific and technical facts, but more refined analyses would be required prior to implementation of individual elements. The map information shows general areas of the river system where actions may be taken, but the ultimate decisions on specific locations and prioritization of these actions remain with the local jurisdictions and the community.

This section begins with a description of an alternative future vision to the one described at the end of the previous section. This vision is intended to articulate potential opportunities with mutual benefits to both the natural and human environments. Realization of these opportunities will be dependent on an integrated management of the river system. A conceptual framework for the IRMS is then described with its foundation built on the goal of restoring and enhancing salmon habitat while reducing flood risk to the human inhabitants in the river system. Key principles of the framework are described including those concepts related to flood risk reduction, salmon recovery, and landscape ecology.

Guided by the key principles, and the findings from the opportunities and constraints evaluation, specific strategies and actions of an IRMS are then developed. For the purpose of this work, strategies are defined as the application of the key principles to the unique conditions of the river system landscape. Actions are defined as activities that can be taken to support one or more strategies and may involve physical manipulation of the river system (structural action) or policy changes (non-structural action) to achieve project objectives. Strategies and actions are described in context with the landscape zones developed in the previous section, including uplands, lowlands and estuary.

The section ends with a description of a potential IRMS for the Tillamook Bay river system. A map is used to describe how a set of actions may be applied at the different spatial scales of the Tillamook Bay system to achieve strategies for reducing flood risk and restoring salmon habitat and recovering fish populations. The IRMS includes provisions for management and maintenance of the river system and addresses the need for changing our institutional system so that permitting and other regulatory actions better serve the intent of an integrated approach to managing river systems.

8.2 A Vision for the Integrated Management of the Tillamook Bay Watershed

This section provides a vision for how the Tillamook Bay river system might look and function in the future, under an integrated river management strategy that is driven by the mutual goals of reducing flood hazards to humans and protecting and restoring habitat for fish and wildlife. This vision is presented as a general narrative that addresses how key issues in the Tillamook Bay system, that have been identified through a characterization of the river system, an assessment of historic disturbances and the current state and future trends in the river system, might be resolved. The narrative is intended to instill an understanding for the scope and elements of an integrated river management strategy for the Tillamook Bay system and set the stage for the development of actions to fulfill the strategy.

The Strategy

It is several years in the future, and the people of Tillamook have just experienced another severe winter flood event. After years of being besieged by floods, the people of Tillamook have adopted a strategy to coexist with their dynamic landscape dominated by rivers and the tides. The strategy involves managing the river system in a way that allows the rivers to overflow and the tides to ebb and flood in a more natural manner, for the primary purposes of reducing flood risk to the human population and restoring habitat for fish and wildlife species. The strategy is integrated, that is, it is based on considerations for how one action in the river system will affect another. Over time, natural forces and processes have shaped the landscape of Tillamook Bay region that an increasing number of people now call home. This integrated river management strategy is therefore an attempt to work with, rather than against, the forces of nature to increase the safety of the residents and sustain the other species that have evolved within the river system.

A river system represents the primary mechanism for the movement of water, sediment and organic matter within a drainage basin. Coastal drainage basins, such as the Tillamook Bay Basin, consist of three main landscapes-the uplands, lowlands, and estuary. Across these landscapes, the hydrologic cycle-the continual movement of water, from rain, to runoff, to evaporation-operates unceasingly and imparts water and life into the river system. The integrated management of the river system begins where a majority of water enters the river system--in the uplands.

The Uplands

The steep, forested slopes of the uplands historically presented a first line of natural mechanisms to moderate the effects of rain and snow falling on the land. Live and fallen needles and leaves of trees and other vegetation provided surfaces to intercept, trap, store and evaporate water before it coursed down the steep inclines in the upper reaches of the river system. The forested uplands provided, and continue to provide, a valuable natural resource in wood products to the region. Forestry practices in the uplands have changed to selective cutting based on natural drainage patterns and runoff and sedimentation processes, and not rigid boundaries. A primary consideration is to manage more closely the harvest of trees in regions of the uplands where precipitation-rain and snow--is more intense and where evaporation rates are higher. The strategy of using vegetation to intercept and evaporate, or transpire, precipitation where it lands helps to return the balance of water in the river system to more natural levels and represents the first line of natural flood defense in the managed river system. The altered harvesting procedures have restored the frequency of debris flows and landslides to a less frequent and more natural periodicity. This has reduced the sediment loading in the downstream reaches where flooding is most damaging.

The precipitation that collects and runs off the forested uplands courses down steep tributaries of the river system. In these headwater reaches, even small quantities of water have tremendous amounts of energy to scour and transport sediment and debris. In selected locations of the river system, the natural accumulations of wood debris, or wood jams, have been restored to reduce the energy of flowing water and trap sediment within the river system. Wood jams were historically prevalent throughout the river system and offered a natural mechanism of moderating floods. Based on observations of natural wood jams and using innovative *engineering, log jams have been designed and constructed using large wood to attenuate flood flows, capture sediment and provide habitat for fish and wildlife. GIS mapping techniques are used to locate reaches in the river system where wood jams would tend to occur naturally and be most beneficial The construction of the jams is governed by hydraulic and structural engineering principles to reduce the risk of failure and downstream impacts. The engineered log jams also serve to collect debris that could accumulate at downstream lowland valley structures, causing blockages, flooding and possible failure of structures.*

The culverted road and railroad crossings, once numerous throughout the uplands, have been removed or enlarged to allow a more natural movement of water and sediment. These upland actions have significantly lessened the unraveling of the natural slopes and erosion of constructed fill embankments. The upstream management of precipitation and the sources of runoff now helps to extend the life of many of the existing culverts by keeping the quantities of water and sediment closer to the design values used to originally build the structures. Where fish passage is required, culverts have in many places been replaced by larger openings that allow an unconstrained flow of water and sediment and offer the fish a seemingly natural corridor for movement.

The Lowlands

The river system experiences an abrupt steep to flat transition from the uplands to the lowlands. This transition leads to a significant reduction in the slope of the river channels and results in river reaches where sediment is deposited and transported in a dynamic fashion. These are the reaches that exhibit the most significant natural changes in the last 50 years. Water is spread across the heads of the lowland valleys and sediment is transported across the floodplains. Fine sediments are deposited in restored riparian and wetland areas, thus improving the wetland productivity and reducing fine sediment deposition further downstream across pasturelands.

Since the lowlands are the most highly developed and inhabited portion of the river system, the complex patterns of water and sediment flow that occur here are extremely important to understand to protect land uses, but difficult to predict and manage. Land managers now use a dynamic computer model of the lowland floodplains to help guide the complex decisions necessary to reduce flood risk to humans and increase habitat for fish and wildlife. The model is dynamic because it can simulate the complex interaction of river flow and tidal action over time, predict the rate of sediment deposition in critical areas and determine critical thresholds to identify when maintenance activities are necessary. The model also shows how one action in a river system may affect another portion of the system.

Even with the actions taken in the uplands to reduce the variability and amount of water, sediment and other materials transported downstream, significant quantities continue to reach the lowlands. In the vicinity of the upland-lowland boundary, efforts have been taken to manage the active flow of water and sediment. The natural erosion and deposition patterns of the rivers have been observed and harnessed to guide the accumulation of river gravel and cobbles in accessible off-channel areas for harvesting in a sustainable manner. Continual monitoring and measurement of sediment quantities removed ensures the harvest of these materials takes place at a rate that does not exceed the natural upstream supply. In this way, impacts such as accelerated streambank erosion and channel incision to downstream channel reaches, that could become "starved" from the lack of sediment, are reduced.

Within this active floodplain zone, rows of native trees and shrubs, similar to hedgerows, have been planted to slow and detain overbank flows. Much like snow fences, *the hedgerows filter flood flows while encouraging the deposition of sediments and flood debris in locations that would be accessible for maintenance and removal following a flood event. These floodplain hedgerows also help guide floodwaters towards flood relief routes and overflow routes that divert excessive flood flows away from livestock refuge areas, high value agricultural zones and urban development. The restored floodplain areas also provide flood storage thus reducing the volume of water that has to be passed through the lower reaches - particularly at high tide conditions.*

Continuing downstream along the lowland rivers, plantings of native trees and shrubs have been re-established along selected reaches of river and slough channels to provide complexity for fish and wildlife habitat, shade for cooler water temperatures and a source of detritus, and other organic matter for natural food supplies to the river system. The location of the plantings, or shelterbelts, have been strategically decided with respect to the seasonal angle of the sun and direction of the winds, so as to maximize the benefits of these natural features. The width, or landward extent, of the shelterbelts are not imposed as a fixed width along a reach of river, but rather they are designed to fit the lay of the land and accommodate long term natural processes of river channel change and human land uses. Once again the floodplain computer model has been used to guide decisions concerning the location and benefits of shelterbelts to improving habitat for fish and wildlife and reducing flood impacts to humans.

The planting and ensuing growth of floodplain vegetation along the margins of pasturelands has reduced flood impacts by trapping and filtering out flood debris and sediments close to the river banks while managing the extent and depth of these flood deposits across high-value agricultural lands. This is important in very low-lying areas to ensure that the pasture elevations increase at a rate that equals or exceeds that of sea-level rise. This strategy will help maintain the area of viable pasture and reduce the duration of waterlogged soils or standing water. The growth of vegetation along the edges of existing or recently setback dikes and levees has lessened the erosive energy of river currents and has helped to reduce maintenance costs and extend the life of these flood control structures.

Selected river reaches formerly constrained by levees and dikes have been re-connected to their floodplains and marshplains by selectively setting back levees and dikes, excavating terraces along the channels and establishing overbank flood relief routes. These actions have allowed sediment-laden flood waters to overflow and deposit fine silt and sands outside of the river channel. The resulting cleaner gravels in the rivers have led to better habitat for aquatic insects-the foundation of the aquatic foodchain--and have improved spawning habitat for the salmon. The reconnection of the floodplains has also increased the flood carrying capacity of river channels. By giving the rivers "elbow room" in these ways the erosive energy and depths of the floodwaters have been reduced and streambank erosion problems have become less severe and more manageable.

Where levees and dikes have been setback on pasturelands, the traditional abrupt prismatic shape of these flood control structures has been changed into a wider bermed structure with gradually sloped grassed surfaces that allows farm animals to graze on the structures themselves. The flatter slopes of the grassed berms are more resistant to erosion from overtopping flows and require less long term maintenance efforts and expenses. These new grassed berms also create refuge areas and egress routes for livestock during flood events. The crest elevations of the setback grassed berms have been kept at the same elevation as the original structures to provide the same level of flood protection, or in some cases raised or lowered to meet other river management objectives. The floodplain *model has been intensely used to explore the best alternatives for moving and shaping levees and dikes, changing the volume of fill material in the floodplain, and guiding the movement of floodwaters.*

One significant use of the model has been for the design of flood relief routes that carry floodwaters efficiently through the many floodplain encroachments in the developed portions of the lowlands. The routes have been aligned to follow the patterns of flooding and the natural drainage patterns of the land. In many cases where the lowland flood relief routes and river channels encounter bridges, the bridge and approaches to the bridge have been changed so that flood water and debris pass through more efficiently, while reducing the potential for scour of bridge foundations. These changes have involved modifications to the bridge abutments, piers, height of the bridge deck, and road approach fill embankments. For some bridges, the upstream edges of the bridge piers have been changed to reduce the potential to collect and hold woody flood debris. The changes have made the piers more streamlined to flows so that floating debris is separated and diverted around the otherwise blunt pier face, and carried downstream through the bridge and into the estuary. For bridges presenting a more significant floodplain obstruction, the earthen fill material for the road approaches has been removed and the land graded down to elevations blending into the natural floodplain contours. The new road approaches are elevated on pilings over the reconstructed floodplain, allowing floodwaters to flow more freely under the roadway, much like the turn-of-the-century railroad trestles that still cross some waterways in the Tillamook lowlands.

The Estuary

The series of dikes and levees in the tidal estuary of Tillamook Bay were first established to prevent the intrusion of saltwater onto tidal lands reclaimed for pasture. The structures have served this purpose, but have also served as a trap for freshwater river overflows trying to flow back into the bay as flooding recedes. Building upon earlier efforts in Tillamook started in the late 1990s, old tide gates have been enlarged and some have been removed to increase the speed and efficiency in draining the protected pasturelands. In some cases, special tide gates have been installed that allow interior tidal flooding up to an established elevation and then close if storm surges threaten higher water levels. These gates have been used where tidal sloughs have been restored for chum salmon habitat and where adjacent pasturelands can tolerate some tidal inundation. These new structures have also been sited in a manner to spped the drainage of flood relief routes so that far less land is now inundated for long periods of time after major flood events. Local property owners and farmers gather in the County offices after major floods and use computer model simulations to observe the success of the flood management strategy compared with the massive flood damages incurred during the 1980s and 90s during lesser events.

Just as river levees and dikes have been setback to lessen the force and depth of floodwaters, tidal levees and dikes have been selectively setback to reduce the damaging effects of high tides, waves and overtopping. The setbacks have been established to restore tidal inundation to the marsh fringe of the bay. The increase of inundated area increases the tidal prism associated with tidal channels tributary to the bay. The tidal prism is the average volume of water that flows in and out during a typical tide cycle. The increased tidal prism volume naturally maintains larger channel openings that help convey higher flows during river floods. The restoration of tide lands in this way has allowed the ebb and flood of the tide to restore and maintain natural shapes of tidal sloughs and marshes and has reduced the need for some maintenance dredging. Dredging increases channel volume at the dredged location in the short term, but if it occurs below a low tide level, it will *not increase the active tidal prism volume and will not contribute to a more natural way of sustaining channel openings.*

Water quality components of the computer model are used in a predictive mode to estimate bacteria and other contaminant loadings to the bay. This results in a greater understanding for when to schedule shellfish bed closures. In addition the model provides information that enables the duration of these closures to be shorter than before the integrated modeling/monitoring program was in place.

8.3 Fundamental Principles of the IRMS

The framework for an effective IRMS is built upon basic principles. The primary principles are associated with those activities that support the goal of the project to achieve flood risk reduction and salmon recovery. Since an IRMS involves a river system and its relationship to the landscape, principles of landscape ecology are also considered. The unique aspect of this project is that these principles are considered in an integrated manner, not as discrete sets of principles governing independent disciplines. The framework for an effective integrated river management strategy is already in place, developed from lessons learned by others in the respective disciplines of flood management, salmon recovery and landscape ecology.

For flood risk reduction, the Midwest Flood of 1993 resulted in a comprehensive assessment of problems and opportunities for river management. The findings of the investigations, referred to as the Galloway Report, articulated the basic principles and strategies for effectively managing the effects of floods. Other flood experiences in the United States since then-the Southwest floods of 1994, the Pacific Northwest floods of 1996, the Northern California floods in 1996-97 and the North Dakota Red River flood in 1997 - all verify the need for and the elements of an effective river management strategy. For salmon recovery, the proposed strategy needs to be consistent and complement other regional initiatives, including the Governor's Salmon Recovery Plan, OWEB, the Northwest Power Planning Council multi-species framework, the Independent Scientific Group (2000), and the National Research Council (1996).

8.3.1 Flood Risk Reduction Principles

The fundamental principle that forms the foundation for this project is the premise that requirements for effective flood risk reduction and salmon recovery are largely complementary. Restoring river systems and functions to accommodate flooding and improve the effectiveness of existing flood control works are both key components of a successful river management strategy. There is substantial consensus that successful integrated management of a river is best achieved with the restoration of the natural physical processes that form the habitat sustaining the ecosystem. In river systems, the dominant processes are floods, the movement of sediment and organic material, and the free interaction of flows between river channel and floodplain.

Based on our lessons learned from flooding, together with recent recommendations for successful habitat protection and restoration in the Pacific Northwest, several key principles for flood risk reduction should be considered (Box 8-2).

8.3.2 Salmon Recovery and Conservation Biology Principles

Principles for salmon recovery (Box 8-3) can be focused on protecting and sustaining the basic life cycle requirements necessary for the survival of the species. These basic requirements for habitat include: spawning, rearing, passage, as well as suitable food sources, refuge areas and management of potential predation or harvest. In a sense, this results in a trend toward ecosystem recovery rather than just species recovery.

Principle 1: Longitudinal connectivity. There is a natural longitudinal connectivity from hillslopes, along the stream network to the ocean. The condition of the stream channel is a direct reflection of the conditions of the uplands. Soil disturbance in upland areas has a direct effect on the quality of the stream network. Identification and protection of these networks throughout the hillslope areas, which allow for flood pulses and sediment transport processes, will enable more cost-effective management strategies to protect infrastructure and land uses. Among the most significant landscape impacts to hillslope processes is the density and condition of the road and culvert system. In the absence of the historic quantities of large wood mediating landscape processes, the stream network has enough energy now to deliver excess sediments to stream channels, which damages spawning gravels and can cause problems for infrastructure maintenance.

Principle 2: Lateral connectivity. Lateral connectivity is the linkage between the river channel, its floodplains and tidal marshes. Floodplains are formed by the processes of flooding, sediment transport, and deposition. In the estuary, tidal marshes form the link between channels and terrestrial ecosystems. This dynamic interaction is the physical basis of the fish and wildlife habitats associated with rivers and floodplains. Resource management philosophy is now shifting toward the reconnection of floodplains and tide marshes which have been disconnected from the adjacent stream channel. When this natural connection is restored, sustainable habitats can regenerate spontaneously, even if these processes may require years to decades to occur. Floodplain and tidal marsh hydrological and geomorphic functions can guide the basis of land use management. The boundaries of a designated flood, such as the 5-year flood, could provide the basis for minimum limits for protection of the stream corridor network. Local tide gages could provide data for minimum dike setbacks in diked tidal wetlands. The cycles of flooding, fires, channel migration and other natural disturbance are essential to the structure of maintenance of habitat (Bisson et al., 1997). Allowing natural channel meandering to occur within predetermined limits and reestablishing lateral connectivity are important physical processes that govern the ecological value of habitat.

Principle 3: Protection of plant communities. Plant communities that regenerate along the river corridor have evolved under a historic flood and tidal disturbance regime, and are therefore able to establish at the proper soil, moisture and salinity conditions that enable them to grow to maturity and reproduce. Riparian, floodplain, and tidal marsh plant communities can withstand flood flows, high velocities, sediment deposition and scour. However, it is important to verify through field monitoring or analysis that these plant communities can survive in channelized reaches with levees constricting the flows. With little management effort, these plant communities can provide the functions of flood attenuation, fish habitat, water quality improvements, increased summer base flows, increased channel and bank stability, fish and wildlife habitats, biodiversity conservation and a host of other functions which directly benefit human society. To achieve these desirable, multi-functional goals, the width of the floodplain corridor or area of tidal influence must allow adequate area for the growth of the riparian, floodplain and tidal marsh plant communities. Designation of this appropriate floodplain or dike setback width to reflect the ecological functions of streamside plant communities is a key component of environmentally sensitive river management for flood risk reduction. It is also important to note that the scour and erosion of some vegetation and subsequent re-colonization is an important process in a healthy riparian corridor, as it results in a diversity of vegetation types and ages.

Principle 4: Sustainable production, recruitment and retention of large wood. Large wood historically provided most of the physical structure of Pacific Northwest stream ecosystems, and much of the attenuation of sediment pulses delivered to the stream by hillslope processes such as landslides. Large wood structures are essential components of the habitats needed to sustain salmon populations at every level of the landscape, from the hillslope to valley floor, in-stream, in-estuary and even into the ocean (Maser & Sedell, 1994). Recovery of adequate volumes of instream large wood is a high priority for river corridor management where salmon populations are threatened. The use of large wood structures is potentially compatible with flood risk reduction, when adequate area is given for the floodplain to convey floodwaters. In addition, the strategic placement of large woody debris can function as a useful management tool in preventing accumulation of flood debris as critical locations such as road crossings. Protection of existing large wood in streams is a high priority at a policy level and for consistent implementation.

Principle 5: Protect the best, restore the rest. This principle is a general rule of thumb derived from the field of conservation biology that considers spatial scales. If stronghold populations exist, then these will generate more fish than can be sustained in the available habitat, and the population will spread gradually to neighboring watersheds. Stronghold populations also indicate that the physical conditions of the watershed are such that the population is unlikely to be decimated in a single, catastrophic event such as fire or flood. Protection of relatively intact ecosystems provides more certainty for success and is less expensive than efforts to restore degraded systems (Nehlsen, 1997). Federal, state, and local resource managers, affected landowners and the community should help in this type of prioritization.

8.3.3 Landscape Ecology Principles

The principles proposed in the IRMS are inter-disciplinary, and the strategy of increasing diversity throughout the river system and restoring natural process can be expressed in the terminology of the landscape ecologist (Box 8-4). The principles of landscape ecology indicate structurally complex landscapes are generally higher in biodiversity and are therefore more ecologically significant than simplified landscapes. The landscape of the Tillamook basin is complex, encompassing steep headwater streams to riparian corridors, wetland environments and an extensive estuarine system, all in a relatively small geographic area. Biodiversity in this basin is therefore, very high, and accounts for the high ecological significance of this basin within the Pacific Northwest Coastal Ecoregion. This biodiversity increases the resilience of the Tillamook Bay ecosystem to change, and should be preserved.

8.3.4 Sustainability Principles

Sustainability is difficult to define and difficult to measure (Bell and Morse, 1999). For the purposes of the IRMS it will be simply defined as ensuring that the value of efforts taken as part of the IRMS do not diminish through time. For the IRMS to be sustainable, several principles need to be considered (Box 8-5).

Commitment of the stake-holders. The IRMS must maintain the commitment of the stake-holders, politicians, public interest groups, land-owners and agencies. Local ordinances and legislation may help ensure this commitment and funding mechanisms.

Secured funding. Funding must be secured for implementation, regulation and maintenance of IRMS actions. In addition, actions like those related to logging or agriculture must be fiscally viable.

Resilient ecological and physical processes. The IRMS should be resilient to episodic and chronic changes to the system. Episodic events might include floods, fires and insect or disease outbreaks. Chronic issues cover processes such as the gradual sedimentation of tidal channels if there is insufficient tidal prism to maintain the current channel dimensions. As an example of a local indicator of sustainability, consider a tidal reach that is diked on both banks. At low flows, there may be insufficient scouring action of the channel bed by tidal action and the channel gradually fills with sediment. On the next significant flood, the deposited material may or may not be scoured and the level of flood protection varies accordingly. One solution may be dredging. However, the long term sustainability of this flood management action is contingent on a long term funding source.

A more sustainable alternative could be a combination of levee setbacks and tidal marsh restoration. The marsh restoration increases the volume of water exchanged on the ebb and flood of the tides and increases the scouring of the channel bed, thus maintaining a channel that is closer to an equilibrium condition. This condition requires less human intervention to maintain. This dynamic equilibrium condition represents the river condition that is adjusted to the current hydrology and tidal processes and represents the "minimum maintenance section". Monitoring and computer simulations can identify what these conditions are for each river system. This represents one potential example for how sustainable conditions might be achieved through an IRMS.

The IRMS is multi-faceted and will be implemented over a significant period of time - this also implies that sometimes one objective can be achieved in different ways. Due to the complexity of the ecology, hydrology, natural perturbations of the river system through flood or fire, and linkages with current land use practices, it is not possible to develop the definitive solution for the next few decades in the Tillamook Basin. However, it is possible to define common objectives and performance criteria to assess, on a regular basis, whether the stake-holder and funding commitments to the IRMS are sustainable, and whether the evolution of the river system is on a trajectory to achieve natural sustainability. Field monitoring can be used to ensure the level of flood risk expected by the community is maintained while other ecological and agricultural goals are achieved. This concept is discussed further in Section 8.6.

8.3.5 Cumulative Effects Principles

Cumulative effects have long been recognized in watershed management, and analyses for these effects are required in Environmental Impact Statements. General principles for the evaluating cumulative effects are listed in Box 8-6.

Cumulative effects may be negative impacts or benefits. Often physical parameters can be measured as an indicator of cumulative effects in the watershed. For example, water temperature is a function of hydraulic geometry (width-depth ratio), geomorphic diversity, groundwater levels, vegetative cover and streamflow. Water temperature is easily monitored, and the recording of trends in water temperature can provide an understanding for the effects of enhancement actions through the river system and over time and at specific locations.

8.4 Summary of Potential IRMS Strategies and Actions

8.4.1 Overview

Using the findings from the opportunities and constraints evaluation and guided by the fundamental principles just described, potential strategies and actions for a Tillamook IRMS were developed. For the purpose of this effort, strategies are defined as broad concepts for achieving the goals and objectives of an IRMS and actions are more specific activities that can be considered to implement the strategy. In this section, upland, lowland and estuary IRMS strategies are introduced together with a mix of structural and non-structural actions.

Strategies. Information derived from the characterization of the Tillamook Basin river system was evaluated to develop potential management strategies. These strategies support the fundamental principles of the IRMS and are applied with consideration for the landscape zones. In general, management strategies call for the attenuation of water and sediment flows in the active floodplain zone, and the conveyance of water and sediment through the floodplain and tidal zones. These attenuation and conveyance zones, respectively, are represented as overlays on the main lowland landscape zones (Figure 8-1).

Estuarine areas represent the most dynamic parts of the system, because tidelands experience the daily ebb and flood of the tide. Strategies for managing the estuary zone of the river system generally consider restoring the natural mixing of fresh and salt waters, and reducing the inland flood effects of backwater from the bay on the lowland river reaches. The natural resiliency of the estuary to recover landform and vegetation with the restoration of tidal flows was considered, together with the opportunities for salmon habitat recovery and the constraints imposed by existing human land use in the estuary zone.

Actions. Potential river management actions were identified to support and implement the strategies. For this planning-level investigation, a list of potential actions was initially developed based on structural and non-structural actions commonly employed in flood management. The list was also tailored to include potential actions that could be implemented in the unique physical setting of the Tillamook Bay Basin. Table 8-1 provides a summary of these actions with respect to their potential benefits to fish, wildlife and human populations.

Action areas within the tidal, floodplain, and active floodplain zones were identified. In the tidal zone, land slope and tidal elevations were used to determine the minimum dike or levee setback needed to restore tidal action within the zone. In the floodplain zone, topography and flood flow routing information from FEMA study and maps were used to identify potential flood flow conveyance routes. In the active floodplain, historic channel locations were overlaid to delineate the meander corridor through the active zones where energy dissipation might be accommodated. Table 8-2 provides a summary of the actions in Table 8-1 but relates them to the zones and action areas within the system where they might be implemented. The underlined actions shown on the two tables were selected as examples for further consideration in one potential IRMS for the Tillamook Bay lowland and estuary.

Lowland IRMS map. Strategies and actions were spatially located on a map of the south Tillamook Bay lowlands (Figure 8-1). The spatial features presented here represent one potential combination of strategies and actions that could comprise an IRMS for the Tillamook lowlands. The feasibility and appropriateness of these features needs to be further refined and evaluated using field investigations, hydrodynamic modeling and landowner consultations. Selected strategies and actions for this IRMS map are briefly described in the following sections. Upland management strategies are reviewed but not mapped.

8.4.2 Fundamental Upland Management Strategies

Upland areas represent the largest portion of the Tillamook Basin and serve as source areas for many of the system's physical and biological processes. The large expanse of the upland landscape collects precipitation and conveys water, sediment and organic materials through the river system to the lowlands. Since the upland and lowland portions of the river system are so strongly connected, successful management of the lowlands begins with proper management of the uplands. Fundamental strategies for managing the uplands to improve the success of a lowland IRMS include the following:

Manage the Runoff of Water Where it First Falls as Precipitation. Upland management strategies are most effective when applied at the source of inputs to the river system. Since precipitation typically first encounters vegetation as it falls, management of vegetation in the uplands is of primary importance. Vegetation serves to absorb, detain and transpire precipitated water. This process delays in time and reduces in volume the water reaching the river system. Precipitation that reaches the ground either runs off or is infiltrated. Infiltration, like vegetative transpiration, both delays and lessens precipitation entering the river system. However, since the upland soils are generally shallow, the potential for infiltration depends largely upon the underlying geology. Nonetheless, the combined reduction in water volume from transpiration and infiltration contributes to a reduced downstream flood risk and a more even distribution of water throughout the watershed. Management of these upland areas should receive higher scrutiny to protect and maintain the natural ability of the uplands to moderate the contribution of water to the river system.

Manage the Recruitment and Movement of Large Wood in Upland River Reaches. Montgomery and Buffington (1993) found that channel morphology at the reach scale is controlled by hydraulic discharge, sediment supply, and large woody debris (LWD). Stable wood in stream channels can have a significant hydraulic effect by increasing boundary roughness and forming flow obstructions. Large wood plays an important role in the formation and sustenance of aquatic habitats. The presence of flow obstructions is probably the single most effective means of increasing the diversity and range of physical habitat. Large wood can moderate the effects of flooding in lowland reaches of a river system by increasing energy losses in water flow and providing sediment storage. Management of land use in the uplands can ensure the recruitment of large wood to the river system, helping to attenuate downstream flood and sedimentation effects, thereby contributing dramatically to both upland habitat restoration and lowland flood risk reduction.

Manage Stream Impacts at Crossings. Road systems have been extended across the uplands for access to natural resources and for transportation connections to other points within and beyond the basin. Significant impacts may result where the fixed road system intersects the dynamic river system. Management efforts need to be focused at these locations to ensure the downstream movement of water, sediment and organic material is not excessively obstructed or cumulatively impacted. Where these system intersections occur along river reaches traveled by salmon, management efforts need to ensure the successful upstream passage of adult salmon and the safe downstream passage of juvenile salmon.

8.4.3 Combined Floodplain and Active Floodplain Zones

Strategy and Actions. Strategies for the floodplain and active floodplain zones of the lowland valley should be to attenuate flood flows and manage the overbank flow and distribution of floodwater, debris and sediment. The primary actions considered for common use in both the active floodplain zone and floodplain zone were floodplain shelterbelts, riparian plantings, alternative grazing practices, levee modifications, floodplain restoration and floodplain structure modifications. These common actions are described below with additional actions more specific to the active and general floodplain zones described in the following two subsections.

Floodplain Shelterbelts. Shelterbelts are plantings consisting primarily of tall trees, intended to benefit fish and wildlife and agricultural interests. They would be most beneficial for fish where they are planted along the northwest edges of streams, such that leaves, twigs and other organic matter are blown directly into the water and contribute to the food source for benthic invertebrates and, in turn, for fish. Shelterbelts placed along the southern edges of streams would shade surface waters to moderate water temperatures and improve water quality for fish and other aquatic organisms (Figure 8-2). Shelterbelts have been used for centuries as a method to protect agricultural crops and soils from wind damage and erosion. Shelterbelts along the northwest edges of existing or restored floodplain wetlands would reduce summer wind speeds and reduce evaporation rates from wetted areas. This would help moderate excessive changes in the seasonal water balance in agricultural areas.

Riparian plantings. Riparian plantings were considered for use throughout the lowlands. Plantings can be utilized anywhere in the lowlands, but would be favored on riverbanks and restored floodplains. Riparian plantings should be wider in the active floodplain zones because of the potential for channel meandering.

Natural Levees. As sediment-laden floodwaters overtop a riverbank and overflow onto the floodplain, suspended sediment is deposited. The portion of the floodplain immediately adjacent to the river channel is most effective in trapping fine suspended sediments and typically forms natural levees -- low mounds of earth that become vegetated and provide functions similar to those of constructed levees for lower-elevation, higher-frequency flood events. If land use activities encroach on the floodplain, the value of this floodplain function may be reduced and an increased amount of fine sediment may be deposited in the stream channel itself, leading to increased embeddedness of salmon spawning gravels and impacts on fish production. By setting back constructed levees, the floodplain may regain its function to serve as an effective sink for fine sediment, silt and clay sized particles suspended in flood flows. The development of a natural levee on the riverbank may be replicated by constructing low mounds of earth (Figure 8-3).

Vegetated Levees. Levee failures are often attributed to excessive changes in soil pore water pressures as the earthen structure experiences the rapid rise and fall of floodwaters. The root mass of riparian vegetation can moderate this soil condition and help keep the soil structure intact (Figure 8-4). The stems and leaves of plant materials can also reduce the surface erosion of levees by reducing floodwater velocities and wave action. The existing structural integrity and original design assumptions of any levee or other flood control structure should be reviewed before vegetation is introduced, however.

Floodplain Rotational Grazing. The flat terrain characteristic of lowland floodplains often provides easy river access for livestock watering. River bank disturbances and water quality degradation may result as livestock trample the fragile land-water boundary. River bank erosion during subsequent flood events may be initiated where riparian vegetation and soil has been disturbed. Fencing is used to control the movement of livestock to and from the river and provides a contained area for grazing. During flood events, fencing can create obstructions to flood flows and trap flood debris, causing local scour and erosion of pastureland (Figure 8-5). The impacts of grazing can be lessened if cattle are moved on and off land parcels on a rotational basis to improve the production of the land for farming and ecological purposes. Several farms in the Klamath Basin are experimenting with this approach (PWA, 1998).

Streamlined Floodplain Structures. The geometric configuration of infrastructure built on floodplain lands reflects traditional design considerations and the economical use of materials and land. These features may result in obstructions to flood flows. Innovative uses of floodplain vegetation and modifications to the traditional design of floodplain construction to streamline flood flows may reduce flood impacts (Figure 8-6). The streamlined movement of floodwaters around obstructions may lessen the potential for damages from floating debris and reduce localized erosion.

Levee Setbacks with Floodplain Terracing. To reduce flood elevations and increase the ability of a river reach to carry floodwaters, it is necessary to increase the flow area of the river channel. Levee setbacks together with terracing of the floodplain would accomplish this and also provide ecological benefits for fish and wildlife habitats (Figure 8-7). Reconnection of a seasonal flood pulse to floodplain lands would increase the direct deposition of organic materials to the river system and provide food for aquatic organisms. The grading of river banks may also provide better access to the river for recreational purposes.

8.4.4 Active Floodplain Zone

Strategy and Actions. The specific strategy for this zone (Figure 8-1) was to attenuate floodwaters and trap sediment and flood debris after floodwaters leave the uplands and prior to their discharge to the downstream floodplain zone. The primary actions considered were the use of floodplain hedgerows and gravel traps.

Floodplain Hedgerows. Hedgerows are strategically placed plantings consisting primarily of short shrubs and are intended to slow and detain overbank flows. Functioning much like snow fences, the hedgerows would be planted densely, but would be permeable enough to filter flood flows while encouraging the deposition of sediments and debris in locations that would be accessible for maintenance and removal following a flood event. The vegetation would be generally placed in rows perpendicular to observed overbank flood flow directions to best retard the movement of floodwaters. The alignment of the hedgerows would be optimized through the use of hydrodynamic modeling, but could be aligned predominantly in a north-south direction to minimize shading on agricultural fields and pasturelands. The composition and density of the rows of vegetation would vary. Thin and permeable rows could be designed to slightly detain floodwaters and filter flood debris. Thicker and denser rows, perhaps constructed with low walls similar to European hedgerows, would be designed where complete flow detention and debris entrapment is desired. Potential hedgerow alignments would be reviewed with landowners and easements would be negotiated to enable the vegetated structures to be laid out to counter anticipated natural flood patterns, as opposed to strictly following existing property boundaries.

Gravel Traps. The active floodplain zone represents a reach of the river system where sediment deposition is prevalent, as material from the uplands is transported to reaches of lower gradient and greater width. The natural erosion and deposition patterns of the rivers would be harnessed to guide the accumulation of river gravel and cobbles in accessible off-channel areas for harvesting in a sustainable manner. Continual monitoring and measurement of sediment quantities removed would ensure that the harvest of these materials takes place at a rate that does not exceed the natural upstream supply. In this way, impacts to downstream channel reaches, such as accelerated streambank erosion, channel incision, and sediment "starvation" would be reduced.

8.4.5 Floodplain Zone

Strategy and Actions. The specific strategy for this zone (Figure 8-1) was to effectively convey floodwaters and sediment though the various human encroachments in the floodplain towards the tidal zone. The primary actions considered were the use of flood relief routes and overflow routes, fill embankment and bridge encroachment modifications, and debris traps.

Flood Relief Routes and Overflow Routes. Land use and generalized hydraulic data were utilized to delineate flood relief routes and overflow routes. The routes were considered for use within the floodplain zone, downstream of the active floodplain zone and upstream of the tidal zone. Flood relief routes would be dedicated easements on floodplain lands, utilized to relieve flood hazards, such as flood elevations and flow velocities, within the same river system. Flood overflow routes would be utilized to relieve flood hazards by conveying flood flows to another lowland river system. The routes were initially laid out according to flood patterns associated with the 10-year flood, with consideration of natural topography and drainage patterns, to promote more natural drainage of floodwaters from floodplain lands. These initial routes were refined in alignment and width to avoid existing land uses such as buildings and public infrastructure. The routes were further refined to include and connect existing wetland communities, and to interconnect proposed riparian plantings to form lowland vegetation corridors for fish and wildlife. The widths of flood relief routes are intended to be defined as best as possible by the existing terrain. Where land elevations are not high enough to contain floodwaters or where existing properties need to be protected, bermed levees (Figure 8-8) would be used to contain floodwaters. The bermed levees would be constructed using land slopes that would allow animal grazing over their crest. Land use practices and infrastructure within the flood relief routes would be reviewed for opportunities to reduce or eliminate obstructions to flood flow.

Road and Railroad Fill Embankment Modifications. Many linear encroachments extend across the lowland floodplains. These built features create obstacles to flood flow and result in unnaturally excessive flow velocities and scour of riparian areas and riverbanks. Fill embankment modifications, using large culverts and other hydraulic openings, would be located where the flood relief routes and overflow routes intersect encroachments and would allow the flow of water, sediment and flood debris across the floodplains in a more natural manner. Flood elevations would be lower, reducing flood risks, and there would be less risk to riparian and channel habitat (Figure 8-9).

Bridge Approach Modifications and Guide Banks. Although bridges are usually designed to span active river channels, they typically constrict the flow of water on floodplains, such that all flow is forced to pass through the opening sized for the shape of the channel. Modifications to bridge approaches would involve the replacement of earth fill with an open viaduct or trestle construction that would allow flood flows to pass under the roadway with less constriction (Figure 8-10). Since the cost of this type of modification to existing infrastructure would be high, this action would be reserved for only the most restrictive bridge crossings. As an alternative, bridge openings would be modified to include the use of guide banks (Figure 8-11). These structures help to streamline the flow of floodwaters through the bridge opening and reduce the potential for erosion of bridge abutments.

Floating Debris Trap. Floating debris is a recurring flood problem that threatens the integrity of bridges in the Tillamook lowlands. Huge rafts of debris pile up on the upstream side of bridge openings and require significant time and resources for removal and disposal (Figure 8-12). Levee setbacks and floodplain terracing would be used in combination with riparian plantings to serve as an off-channel trap for floating debris. Engineered log jams would be located on opposite banks to deflect flood flows and debris into restored floodplain areas. They could also be located at other upstream locations to serve as designated places for debris accumulation.

8.4.6 Tidal Zone

Strategy and Actions. The general strategy for this zone would be to restore tidal flushing action and increase the conveyance of water and sediment from the floodplain zone to the bay. The primary action considered was tidal prism restoration.

Tidal Prism Restoration. Dike and levee setbacks would be considered on tidelands to restore full tidal action on marshlands, which in turn would restore tidal channels and habitat. Restoration of the natural tidal prism, or the volume of water exchanged during a typical tide cycle, would be done by removing and setting back dikes and levees. Since the vertical resolution of the 30 meter DEM used to create the zones is corse, assumptions were made to define a realistic setback distance. Setbacks would be prioritized seaward of the brackish-freshwater interface. A typical marshplain slope of 1:150 was assumed based on a tidal range of 7 feet between MHHW and MLLW. For these conditions, full tidal action would require the restoration of tidelands approximately 1000 feet from MLLW. Restoration would lead to the evolution of complex off-channel tidal slough channels with great habitat potential. Using data from Coats et al (1995), a minimum marsh area of 10 acres was estimated to support a third order tide channel system. For the 1000-foot setback, a 10-acre land parcel would be about 500 feet wide. This minimum parcel size was used for planning purposes.

8.5 IRMS Implementation Considerations

One of the common myths in river management is that flood control, ecological restoration and making the river "look natural" cannot occur simultaneously. From the practical point of view, looking at other successful river management plans, it is evident that the opposite is true. Why are communities looking at multi-objective projects rather than just flood protection? The answer is simple - multi-objective river management also implies multiple potential funding sources.

As an example, the plans for a Napa River Flood Control project for the City of Napa in California was rejected three times by the local community as it benefited only those living in the flood plain. It also called for dredging and massive bank stabilization that would have dramatically impacted the ecology of the river system. The 'Living River Strategy' developed by the local community with assistance from state and federal agencies was a multi-objective project backed by local business, private property owners, special interest groups, local government, and state and federal agencies. FEMA has used this project nationally as an example of a community-based multi-objective approach to flood management. As the project has grown from a project focused only on flood control of a few miles of channel, to a watershed wide initiative, there have been many other benefits and funding sources. Examples of spin-off projects funded from other sources include: the phased restoration of more than 20,000 acres of abandoned salt ponds and diked wetlands; the renaissance of downtown Napa; reduction in flood risks of other communities along the river; watershed wide ecological enhancement initiatives; cleanup of contaminated land; and a coordinated approach to TMDL issues.

Examples of this type of integrated planning are increasing in the United States. The success of future projects depends in large part on key considerations for their implementation based on the "lessons learned" from recent integrated river management strategies (Box 8-7).

Tillamook has an opportunity to be a similar nationally recognized project capable of attracting the diverse range of funds achieved by the Napa Community. Some of the similarities that make Tillamook a prime candidate as a model approach include:

1. Region of great natural beauty
2. Strong tourism economy
3. Severe existing flood problem
4. High quality aquatic environment
5. Watershed is small enough that inter-agency responsibilities can be coordinated more easily

The successful implementation of the IRMS will require several refinements of the concepts presented herein. These refinements include:

1. Support and adoption of the formal plan will be required from landowners, local government, state and federal agencies, and public interest groups. This will be achieved best through a series of workshops and individual meetings with stake-holders.
2. Adjustments to planning and zoning designations where appropriate, and new guidelines for the issuance of permits for activities that affect the aquatic resources and environmental quality of the Tillamook Bay watershed.
3. Computer modeling and related analyses will be required to confirm the expected performance of the actions discussed in Section 8.4, and to evaluate the spatial extent of these measures.

8.6 Monitoring Program and Adaptive Management Considerations

The development of an IRMS is immensely complex and includes ecological, economic, social, hydrological, and cultural issues. The interactions among these issues are difficult to predict, and unforeseen circumstances -- both positive and negative -- may arise as an IRMS is implemented and becomes established over time. Secondly, the conditions in the watershed are not static in time and are subject to the geomorphic evolution of the river system, episodic events such as fire and flood, and external factors such as conditions in the ocean, changes in legislation or funding opportunities.

A cornerstone of the proposed IRMS is the establishment of a clear set of performance criteria, and periodic monitoring standards to ensure that the IRMS is on a trajectory to achieve these performance criteria. The monitoring program will also build our knowledge and understanding of the response of the river system to changes in its watershed. With this knowledge, it is then possible to undertake adaptive management through a review panel of interested parties to alter priorities in management actions to ensure that the objectives of the IRMS are achieved in the most effective manner.

The primary objectives of a monitoring program for the IRMS are to:

1. Coordinate existing monitoring programs and supplement where necessary.
2. Establish a central database of key indicators, computer models and GIS coverages to be used in the assessment of the IRMS.
3. Document changes in flood risk and minimize flood damages for larger events.
4. Document changes in floodplain and marsh plain connectivity with tidal channels and rivers.
5. Document changes in quality and quantity of habitat for indicator species, e.g. Chum salmon, and others identified by the review panel.
6. Monitor changes in vegetation communities.
7. Document changes in access and connectivity to habitat for indicator species through channels during ecologically important times of the year.
8. Monitor costs and ensure that the expenses are sustainable over time.
9. Track changes in habitat, particularly related to indicator, threatened, endangered or "of concern" species.
10. Monitor changes in river and tide channel size and location to anticipate loss of property due to bank erosion or loss of channel flood conveyance (i.e increases in flood risk). Note: it is unnecessary to monitor a large number of sections. A few sections sited in critical positions will provide an indicator of where significant changes are occurring. If these changes are deemed to be significant to flood risk, ecological impacts or other objectives, a more thorough survey could be undertaken.

The computer model currently being developed for the Tillamook Bay by the Portland District, US Army Corps of Engineers will be a valuable decision-making tool if used to assess the effects of sedimentation, dredging, channel scour, salinity intrusion, temperature and water quality under different management strategies. It is also recommended that this model be integrated with a 2-dimensional model of Tillamook Bay so that a better understanding of the link between the hydrodynamics of the bay and lowland river systems can be developed. This modeling approach can then be used to determine water quality, extent of salinity intrusion, and sedimentation trends as a result of different management approaches.

Table 8.3 presents a skeletal monitoring approach with general considerations for all landscape zones of the Tillamook Bay river system. Refined monitoring plans would ultimately be adopted for each landscape zone described earlier. The plan sets out a series of broad objectives, with a column describing the relative importance. For example, flooding in the uplands might be less of a risk than flooding in the city of Tillamook. Associated with each objective is a metric, or parameter, that can be used to quantitatively assess whether the objective is achieved. Associated with each parameter are performance criteria that will determine whether the objective is achieved, or if additional actions are required. The table also gives an indication of how the metrics will be measured. These metrics should be based on existing monitoring data to the extent feasible. Establishing performance criteria and monitoring for adaptive management should be developed in more detail by the review panel, participating agencies and other interested parties.

Table 8-1
Potential Integrated River Management System Actions and Associated Benefits within the Tillamook Bay System

NON-STRUCTURAL ACTIONS	Direct Fish Benefits	Direct Wildlife Benefits	Direct Human Benefits
Mapping and Regulatory Actions			
Update and Enforce Planning and Zoning	✓	✓	✓
Preserve Open Space		✓	✓
More Stringent Floodplain Regulations	✓	✓	✓
Develop Stormwater Management Plans	✓	✓	✓
Acquire Additional Flood Data			✓
Obtain and Maintain Flood Data			✓
Develop a Hydrodynamic Flood/Sediment Model			✓
Maintenance Actions			
Perform Dune and Beach Maintenance			✓
Perform Drainage System Maintenance			✓
Flood Damage Reduction Actions			
Relocate Flood-Prone Structures		✓	✓
Acquire Flood-Prone Property		✓	✓
Elevate Flood-Prone Structures			✓
Floodproof Structures at Risk			✓
Provide Sewer Backup Protection			✓
Promote Flood Insurance			✓
Natural Resource Protection Actions			
Enforce Wetlands Protection	✓	✓	✓
Enforce Erosion and Sediment Control Practices	✓	✓	✓
Employ Best Management Practices	✓	✓	✓
Flood Preparedness Actions			
Establish a Flood Warning Program			✓
Establish Flood Response Protocol			✓
Identify Critical Facilities Protection			✓
Develop Flood Health and Safety Maintenance Plans			✓
Develop Levee and Dam Safety Standards			✓
NOAA Weather Radio			✓
Develop Flood Warning Call Lists			✓
Public Information Actions			
Prepare Detailed Flood Map Information			✓
Develop Outreach Projects			✓
Disclose Real Estate Hazards			✓
Establish Flood Protection Library			✓
Offer Flood Protection Assistance			✓
Offer Environmental Education			✓
Issue Flood Elevation Certificates			✓
Watershed Management Actions			
Develop Watershed Analyses Data			✓
Decommission Forest Roads	✓	✓	✓
Upgrade Forest Roads and Culverts	✓	✓	✓
Adopt System-Based Forest Management Practices	✓	✓	✓
Install Additional Precipitation, Stream & Tide Gauges			✓
Develop Regional Geomorphic Reference Sites			✓
Develop Regional Tidal Prism Data Base			✓

STRUCTURAL ACTIONS	Direct Fish Benefits	Direct Wildlife Benefits	Direct Human Benefits
Levee/Dike Modification Actions			
Adopt New Levee Design Guidelines			✓
Improve Existing Levee Freeboard			✓
Selectively Lower Levee/Dike Crest Elevations	✓	✓	✓
<u>Selectively Setback Levee/Dikes</u>	✓	✓	
Selectively Breach Levee/Dikes	✓	✓	
<u>Enlarge and Berm Levee/Dike Section for Grazing</u>	✓	✓	✓
Modify Tidegates for Fish Passage	✓	✓	
Construct Floodgates/Pumping Stations			✓
<u>Construct Vegetated Levees</u>	✓	✓	✓
River Bank Stabilization Actions			
Repair Existing Revetment In-Kind			✓
Modify Existing Revetment with Vegetation	✓	✓	✓
Construct Biotechnical Bank Stabilization	✓	✓	✓
Remove Damaged Revetment	✓	✓	✓
Perform Regular Vegetation Management			✓
Roadway Improvement Actions			
Reconstruct Restrictive Bridges and Approaches	✓		✓
<u>Modify Floodplain Fill Encroachments</u>	✓		✓
Enlarge Undersized Culverts	✓		
<u>Construct Flood Relief and Flood Bypass Routes</u>	✓	✓	✓
Drainage Modification Actions			
Modify/Relocate In-Stream Flow Diversions	✓		
Construct Storm Sewers			✓
Construct Sedimentation Basins	✓		✓
Construct Storm Water Detention Basins			✓
Decommission Agricultural Drain Tile	✓	✓	
Modify Groundwater Withdrawals	✓	✓	
Channel/Floodplain Modification Actions			
Construct Overbank Conveyance Channels	✓	✓	✓
Perform Repetitive Maintenance Dredging			✓
<u>Remove/Deflect/Trap Floating Debris</u>			✓
Remediate Gravel Pit Excavations	✓	✓	✓
<u>Construct/Streamline Cow Pads</u>			✓
<u>Construct Vegetated Bridge Guide Banks</u>			✓
Construct Grade Control Structures			✓
Remove/Modify Fencing		✓	
<u>Construct Flood Defense Hedgerows</u>		✓	✓
Floodplain Restoration Actions			
<u>Construct Floodplain Terraces</u>	✓	✓	✓
Revegetate Channel Banks	✓	✓	✓
Restore Cutoff Channels	✓	✓	✓
Restore Blocked Sloughs and Tide Channels	✓	✓	✓
Construct Livestock Fencing Along Streams	✓	✓	
<u>Establish Riparian Shelterbelts</u>	✓	✓	✓
Reconstruct Marsh Plain Terraces	✓	✓	
<u>Implement Rotational Grazing Practices</u>	✓	✓	✓

Italicized text refers to FEMA Community Rating System mitigation measuresthat can be used to reduce flood insurance premium rates.
Underlined actions are presented as potential actions for the Tillamook Lowland IRMS and are described in more detail in the text.

Table 8-2
Potential Integrated River Management System Actions Related to Tillamook Landscape Zones within the Tillamook Bay System

NON-STRUCTURAL ACTIONS	Upland Forest Zone	Upland Transition Zone	Lowland Active Floodplain Zone	Lowland Floodplain Zone	Estuary Tidal Zone	General/ Non-spatial
Mapping and Regulatory Actions						
Update and Enforce Planning and Zoning	✓	✓	✓	✓	✓	
Preserve Open Space			✓	✓	✓	
More Stringent Floodplain Regulations	✓	✓	✓	✓	✓	
Develop Stormwater Management Plans	✓	✓	✓	✓	✓	
Acquire Additional Flood Data	✓	✓	✓	✓	✓	
Obtain and Maintain Flood Data	✓	✓	✓	✓	✓	
Develop a Hydrodynamic Flood/Sediment Model	✓	✓	✓	✓	✓	
Maintenance Actions						
Perform Dune and Beach Maintenance					✓	
Perform Drainage System Maintenance			✓	✓	✓	
Flood Damage Reduction Actions						
Relocate Flood-Prone Structures			✓	✓	✓	
Acquire Flood-Prone Property			✓	✓	✓	
Elevate Flood-Prone Structures			✓	✓	✓	
Floodproof Structures at Risk			✓	✓	✓	
Provide Sewer Backup Protection			✓	✓	✓	
Promote Flood Insurance			✓	✓	✓	
Natural Resource Protection Actions						
Enforce Wetlands Protection						✓
Enforce Erosion and Sediment Control Practices						✓
Employ Best Management Practices						✓
Flood Preparedness Actions						
Establish a Flood Warning Program						✓
Establish Flood Response Protocol						✓
Identify Critical Facilities Protection						✓
Develop Flood Health and Safety Maintenance Plans						✓
Develop Levee and Dam Safety Standards						✓
NOAA Weather Radio						✓
Develop Flood Warning Call Lists						✓
Public Information Actions						
Prepare Detailed Flood Map Information						✓
Develop Outreach Projects						✓
Disclose Real Estate Hazards						✓
Establish Flood Protection Library						✓
Offer Flood Protection Assistance						✓
Offer Environmental Education						✓
Issue Flood Elevation Certificates			✓	✓	✓	
Watershed Management Actions						
Develop Watershed Analyses Data	✓	✓				
Decommission Forest Roads	✓	✓				
Upgrade Forest Roads and Culverts	✓	✓				
Adopt System-Based Forest Management Practices	✓	✓				
Install Additional Precipitation, Stream & Tide Gauges	✓	✓	✓	✓	✓	
Develop Regional Geomorphic Reference Sites						✓
Develop Regional Tidal Prism Data Base						✓

STRUCTURAL ACTIONS	Upland Forest Zone	Upland Transition Zone	Lowland Active Floodplain Zone	Lowland Floodplain Zone	Estuary Tidal Zone	General/ Non-spatial
Levee/Dike Modification Actions						
Adopt New Levee Design Guidelines			✓	✓	✓	
Improve Existing Levee Freeboard			✓	✓	✓	
Selectively Lower Levee/Dike Crest Elevations			✓	✓	✓	
Selectively Setback Levee/Dikes			✓	✓	✓	
Selectively Breach Levee/Dikes			✓	✓	✓	
Enlarge and Berm Levee/Dike Section for Grazing			✓	✓	✓	
Modify Tidegates for Fish Passage				✓	✓	✓
Construct Floodgates/Pumping Stations			✓	✓	✓	✓
Construct Vegetated Levees			✓	✓	✓	
River Bank Stabilization Actions						
Repair Existing Revetment In-Kind			✓	✓	✓	
Modify Existing Revetment with Vegetation			✓	✓	✓	
Construct Biotechnical Bank Stabilization			✓	✓	✓	
Remove Damaged Revetment			✓	✓	✓	
Perform Regular Vegetation Management			✓	✓	✓	
Roadway Improvement Actions						
Reconstruct Restrictive Bridges and Approaches			✓	✓	✓	
Modify Floodplain Fill Encroachments	✓	✓	✓	✓	✓	
Enlarge Undersized Culverts	✓	✓	✓	✓	✓	
Establish Flood Relief and Flood Bypass Routes			✓	✓	✓	
Drainage Modification Actions						
Modify/Relocate In-Stream Flow Diversions	✓	✓	✓	✓		
Construct Storm Sewers			✓	✓		
Construct Sedimentation Basins		✓	✓	✓		
Construct Storm Water Detention Basins			✓	✓		
Decommission Agricultural Drain Tile	✓	✓	✓	✓		
Modify Groundwater Withdrawals		✓	✓	✓		
Channel/Floodplain Modification Actions						
Construct Overbank Conveyance Channels			✓	✓	✓	
Perform Repetitive Maintenance Dredging			✓	✓	✓	
Remove/Deflect/Trap Floating Debris			✓	✓	✓	
Remediate Gravel Pit Excavations		✓	✓	✓	✓	
Construct/Streamline Cow Pads			✓	✓	✓	
Construct Vegetated Bridge Guide Banks			✓	✓	✓	
Construct Grade Control Structures		✓	✓			
Remove/Modify Fencing		✓	✓	✓	✓	
Construct Flood Defense Hedgerows		✓	✓	✓		
Floodplain Restoration Actions						
Construct Floodplain Terraces			✓	✓	✓	
Revegetate Channel Banks	✓	✓	✓	✓	✓	
Restore Cutoff Channels			✓	✓	✓	
Restore Blocked Sloughs and Tide Channels					✓	
Construct Livestock Fencing Along Streams			✓	✓	✓	
Establish Riparian Shelterbelts			✓	✓	✓	
Reconstruct Marsh Plain Terraces				✓	✓	
Implement Rotational Grazing Practices			✓	✓	✓	

Italicized text refers to FEMA Community Rating System mitigation measuresthat can be used to reduce flood insurance premium rates.
Underlined actions are presented as potential actions for the Tillamook Lowland IRMS and are described in more detail in the text.

Table 8.3 Skeletal Outline of Performance Criteria for IRMS

Landscape Zone: Upland, Lowland and Estuary

Objective	Metric	Performance Criteria	Methodology	Relative Significance
Flood Management	1. Conveyance 2. Water surface elevations 3. Land use zoning and planning	1. Designated acceptable risk 2. Required maintenance 3. Duration of standing water 4. Flood damages 5. % key floodplain areas undeveloped	1. Periodic surveys of monitoring sections 2. Computer model 3. Flood elevation monitoring 4. GIS land use coverages	High/Medium/Low (depending on region)
Ecological Enhancement	1. Indicator species	1. Abundance 2. Harvest records 3. Redd counts	1. Snorkel counts, stream surveys, electro-shocking, angler reports and other techniques.	High/Medium/Low (depending on region)
	2. Channel response / geomorphic diversity	1. Slope/sinuosity 2. Width/depth ratio 3. Bankfull flow 4. Substrate suitability index	1. Periodic surveys of monitoring sections 2. Pebble counts/bed samples	
	3. Revegetation / bio-stabilization	1. Survival rate 2. Rate of bank retreat 3. % vegetation cover on banks	1. Vegetation transects 2. Cross-section surveys 3. Visual assessments from aerial imagery	
	4. Water quality	1. Number of days in year shellfish beds closed 2. Temperature criteria 3. Flows 4. Turbidity 5. Fine sediment 6. Nutrients 7. E-coli	1. Coordination of current water quality sampling programs 2. Supplemental sampling as found necessary from modeling or other interpretation of existing monitoring programs.	
Maintenance	1. Costs of maintenance 2. Extent of structural bank stabilization 3. Extent of biostabilization 4. Extent of dredging	1. Minimize costs 2. Reduce rip-rap and other structural measures where appropriate	1. Track annual maintenance costs 2. Establish inventory of channel conditions (updated periodically)	High/Medium/Low (depending on region)

Box 8-2
Principles of Flood Risk Reduction

1. Preserve and enhance natural floodplain functions;
2. Avoid and rehabilitate inappropriate uses of the floodplain;
3. Modify susceptibility to flood damage through both modified structural and non-structural management actions;
4. Mitigate flood damages as they occur;
5. Modify the impact of flooding on individuals and the community;
6. Modify flood patterns;
7. Improve the management of watershed land uses;
8. Streamline flood management policy and procedures, and;
9. Encourage the development of shared databases and new technologies to convert data into knowledge upon which decisions can be based.
10. Identify and protect existing habitat that support stronghold populations of species of concern

Box 8-3
Salmon Recovery and Conservation Biology Principles

1. Longitudinal connectivity
2. Lateral connectivity
3. Protection of the plant communities
4. Recruitment and retention of large wood
5. Protect the best, and restore the rest

Box 8-4
Landscape Ecology Principles

1. Landscapes differ structurally in the distribution of species, energy, and materials.
2. Landscapes differ functionally in the flow of species, energy, and materials.
3. Landscape diversity decreases interiors, increases edges, and enhances species richness.
4. Landscape diversity controls species distribution changes.
5. Landscape disturbances increase nutrient flows.
6. Landscape diversity increases flows of energy and biomass across boundaries.
7. Landscapes will develop either physical system stability, resilience, or resistance to disturbances.

Box 8-5
Sustainability Principles

1. Commitment of stake-holders
2. Secured funding
3. Resilient ecological and physical processes

Box 8-6
Cumulative Effects Principles

1. Include past, present and future actions
2. Use natural boundaries, not political or arbitrary ones in resource management
3. Address additive, countervailing and synergistic effects
4. Look beyond the lifespan and areal impact of any one action
5. Address the sustainability of resources, ecosystems, and human communities
6. Employ a whole-systems approach to resource management

Box 8-7
Key IRMS Implementation Considerations

The IRMS will initiate a longterm management strategy that maintains the quality of life for aquatic and terestrial species as well as the community of Tillamook County.

The IRMS does not represent a single project to be undertaken, but a common vision that the community will aspire to in the coming decades. Individual elements of the plan can be implemented as funding for easements, development opportunities, bridge replacement or willingness of individual landowners pose opportunities.

Condemnation of property is not considered an option, but rather voluntary participation to help reduce flood risks to neighbors and maintain or enhance the ecological resources of the watershed.

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